ANTIQUES

THEIR RESTORATION AND PRESERVATION

ANTIQUES

THEIR RESTORATION AND PRESERVATION

BY

A. LUCAS, O.B.E., F.I.C.

CHEMIST, DEPARTMENT OF ANTIQUITIES, EGYPT;
FORMERLY DIRECTOR, CHEMICAL DEPARTMENT, EGYPT

AUTHOR OF "ANCIENT EGYPTIAN MATERIALS"

SECOND EDITION, REVISED

LONDON
EDWARD ARNOLD & CO.

[1932]

Made and Printed in Great Britain by
Butler & Tanner Ltd., Frome and London

PREFACE TO SECOND EDITION

Since *Antiques: their Restoration and Preservation* was written, now eight years ago, the author has been continuously engaged in the work of cleaning and preserving antique objects, partly at Luxor in connexion with the objects from the tomb of Tut-ankh-amūn, and partly at the Cairo Museum with objects from various sources, as a consequence of which a considerable amount of fresh experience has been gained. The methods of cleaning and preserving antiquities have also been occupying the attention of chemists and others elsewhere and the results of much of this work have been published. The demand for a fresh edition has provided an opportunity of making use of this new knowledge to revise the book thoroughly and to bring it completely up to date.

In the Introduction and in Chapters I and II, which together, however, are only a very small part of the book and which are largely descriptive of the underlying principles of the subject, naturally there has not been much scope for change, but, so far as possible, the matter has been made simpler, clearer and

more precise, and fuller explanations and additional examples have been given.

Chapter III, which deals with the application of methods to specific materials and which comprises the greater part of the book, has been almost entirely re-written and much enlarged. Where practically all is new, it is difficult to single out anything for special mention, but attention may particularly be directed to those portions treating of the cleaning and preservation of Metals, Pictures, Plaster and Stone respectively, all of which have been dealt with in an exhaustive manner.

Metals.—The sections on Gold, Lead and Iron have all been completely revised and much new matter added. The alloy Electrum and the metal Tin have been treated of for the first time, though only briefly, as objects of these materials are not common, either in museums or in private collections. The cleaning of Copper and Bronze has been described at great length, this section having been entirely re-written and much expanded, new methods being given and certain methods previously included that have not proved wholly satisfactory on extended trial being omitted. The section on Silver has been revised and largely re-written, and, as in the case of Copper and Bronze, new methods have been added and other methods found less satisfactory have been discarded.

Pictures.—On the methods of cleaning and preserv-

ing pictures much has been written during the past few years and, as it is a subject that merits special attention, it has been dealt with in detail. For the consideration of the appropriate treatment pictures have been divided into five classes, namely, Mural Paintings (Tempera and Fresco) ; Paintings ; on Chalk Plaster ; Paintings in Wax ; Oil Paintings ; and Prints and Drawings. In certain instances where pictures have been cleaned and preserved, the details of the methods employed have been published and a brief account of as many of these cases as could be found is included.

Plaster.—This section has been entirely re-written and much new matter added.

Stone.—This section has also been thoroughly revised and a large amount of new material included.

In addition to the above-mentioned sections, the parts of the book dealing with Bone, Leather, Papyrus and Woven Fabrics respectively have all been re-written and expanded.

Reagents and Solutions Required.—The special section previously devoted to this matter has been omitted, as it has been found more satisfactory that the information should be distributed throughout the book, either in the text or in footnotes.

A. L.

PREFACE TO FIRST EDITION

The literature dealing with methods of treating antique objects, with a view to their restoration and preservation, is very scanty, and all that exists on the subject are the few books and pamphlets mentioned in the Bibliography at the end of the present volume, together with occasional scattered articles in scientific journals and brief notes in archæological reports. The author, therefore, who has made a special study of the subject, and who for two seasons has been helping with the cleaning and preservation of the objects from the tomb of Tut-ankhamūn, has ventured to write a small book in the hope that it may be useful to archæologists, museum curators, collectors and others. The book is admittedly elementary, and the author has endeavoured to be as simple and non-technical as possible. He has also tried to be definite, and where there are a number of different methods to indicate the best. It must be remembered, however, that no one remedy can be of universal application and that each case should be treated as a separate and special study,

and, in order that this may be done, the underlying principles are fully explained. The methods recommended are neither difficult nor expensive.

A certain amount of repetition has been unavoidable, as many of the subjects overlap one another. Some of the instructions and cautions given may possibly appear trivial and unnecessary, but experience proves that many of them are frequently neglected.

In order to save needless repetition, the nature and strength of the materials and solutions recommended for use are described all together at the end of the book.

The common chemical names in ordinary use, whenever they are not wrong, have been employed in preference to others that, although more technically correct, are less well known.

The author wishes to express his thanks and indebtedness to many friends who have generously helped him out of the abundance of their knowledge and experience. The usual references are given in those instances in which methods previously described are referred to.

A. L.

CONTENTS

CHAPTER IV

SIMPLE PHYSICAL AND CHEMICAL TESTS

INTRODUCTION

The work of restoring and preserving antique objects naturally divides itself into two parts: first, the methods; and second, their application.

The methods are scientific and largely chemical. The underlying principles are, (*a*) to ascertain of what material the object to be dealt with is composed; and (*b*) to determine the nature of any change or deterioration that has taken place, as it is only by precise knowledge of the nature of a material and of the nature of any corrosion or decay, that suitable means can be employed to remove the cause of the damage and to ccunteract its destructive results. In order to apply this information, however, there must also be a knowledge of the properties of materials. On these data is based the appropriate treatment necessary to restore the object as far as possible to its original condition and to prevent the occurrence of any further deterioration.

The nature of the material of which an object is composed is often self-evident, and even when this is not the case the knowledge of other and similar

objects, gained as the result of experience, will be found helpful. The nature of the changes and decay that have taken place is often less easy to diagnose. With care, however, and by means of a few simple physical and chemical tests, gross errors on both points may be avoided, and methods of testing therefore will be given. But, as already stated, something more than this is required if serious mistakes in treatment are to be avoided ; thus, for instance, it might be ascertained that a particular vase was made of alabaster (calcite) and that a crystalline efflorescence on the surface was common salt, but before this information could usefully be applied to the cleaning of the vase, it must also be known that alabaster is acted upon by acid, but not by water, and that salt is soluble in water, but not in acid. This knowledge would result in the choice of water and the avoidance of acid for cleaning purposes.

Although the principles on which the cleaning and preservation of antiquities are based demand a considerable amount of scientific and chemical knowledge, the application of these principles is largely a matter of skilled manipulation founded upon long training and improved by constant practice. At one time all work of the nature of that under consideration was undertaken without scientific advice, but now the tendency is often in the other direction, and the

chemist is expected, not only to devise methods, but also to carry them out. The most satisfactory arrangement, however, is to have a small staff of trained and skilled workmen with a consulting chemist, who has specialized in the subject, attached, and every large museum should possess such a staff. For small museums, however, and for work outside museums this is not possible, and the archæologist in the field, the curator of a small museum and the collector must themselves undertake a large part of any cleaning and preservation work required, and it it is for these especially that the present book has been written.

With respect to field work it should be recognized that this must necessarily be only preliminary and in certain cases even crude, owing to the conditions under which it is carried out, namely, absence of suitable accommodation and proper appliances and often lack of time. One frequent and important limiting factor, too, in desert regions, is the absence of a sufficient or suitable water supply for washing objects, the amount available often being small and the quality unsatisfactory, because salty. Field work should be limited to what is sufficient to enable the objects to be photographed, described, and, more particularly, packed and transported in safety. Detailed and final restoration work can only satisfactorily be carried out in a fully equipped workshop

and by trained and experienced men, acting under the direction of the expert. Much, however, can now be done in the field that formerly was thought to be impossible, and therefore was not attempted, and there are few objects, no matter of what kind, or how poor their condition, that cannot be preserved, and no object should be condemned as hopeless until it has been carefully studied and preliminary experiments made, since much that may appear at first sight to be beyond salvation can generally be consolidated and improved sufficiently to enable it to reach the museum, where it can be dealt with further.

Methods of cleaning and preserving antique objects have been practised for so long that it might seem impossible for any that are not at least fairly satisfactory to have persisted, but they do persist, and some that are not only useless, but harmful, are still employed and recommended. This is because such methods give results that appear successful for the time being, and observations are not made, or not recorded, to show the condition of the objects after the lapse of some years.

Before proceeding to details, three further points may be mentioned: first, the necessity for full publicity in respect to methods; second, the responsibility of the task; and third, the pleasure to be derived from it. In work of this nature there should not be any secrets, and details of processes found

satisfactory should be communicated freely, though unfortunately this is not always done. The work is delicate, and the responsibility great, and a little haste, carelessness or lack of knowledge may irreparably damage an object of beauty and value that cannot be replaced. The pleasure of the work needs to be known to be fully appreciated, but it is a real joy to see an object that has entered the workshop dirty, corroded and ugly, gradually improving and finally becoming clean, healthy and beautiful.

Only the best quality materials should be employed. The use of inferior or makeshift materials, when good quality ones are readily obtainable, is false economy of the worse kind and cannot fail to affect adversely the value of the work.

CHAPTER I

RESTORATION

The first step in restoration is cleaning, and this therefore may now be considered.

Cleaning

Manifestly the first thing to be done is to remove superficial dust and dirt. This may usually be effected by means of a small pair of bellows, or of a camel-hair or similar small soft brush. When, however, the surface of an object is manifestly friable or disintegrating, even gentle blowing may be harmful, and in such cases a brush only should be used. A duster should never be employed, partly because what is happening underneath cannot be seen and followed, and partly because a duster is at best a clumsy instrument and may cause damage by catching in corners or in delicate portions of a carving or in loose pieces of inlay, gilt, or paint.

After blowing or brushing off the loose dust, any more adherent dirt may generally be removed by means of water, petroleum spirit (benzine, petrol), or alcohol (pure, uncoloured, about 90 per

cent. strength).[1] The simplest reagent, namely water, should be tried first, unless it is manifestly unsuitable.

The nature of the object determines whether water should be used sparingly or plentifully. In the former case it should usually be applied by means of a piece of sponge [2] or a camel-hair or other similar soft brush, and for small pieces of inlay and for corners by means of a tuft of cotton-wool on the end of a thin piece of wood, such as a match without the head. Each time the sponge, brush or cotton-wool is removed from the object it should be rinsed in clean water before being used again, the water being frequently renewed. When water is applied in quantity the object should be immersed and well soaked. In all cases warm water is better than cold. As a rule filtered river or lake water and any ordinary town supply are sufficiently satisfactory for most purposes, but well water is sometimes salty and may be very salty, especially in countries such as Egypt, and is therefore better avoided, unless it has been tested and proved to be pure. In certain cases the water should be distilled.

[1] Coloured or mineralized (i.e. mixed with paraffin oil) methylated spirit is unsuitable.

[2] Tiny sponges attached to wooden handles are sold by dealers in artists' materials.

Before using water it must be certain that it will not have any injurious effects. This will be known as a rule from the nature of the material or from previous experience, or may be ascertained by means of an experiment on one corner of the object or on a less important object of similar kind. The effects of water on various materials will be described later when dealing with the materials separately, but a few general rules may now be given, to all of which, of course, there may be exceptions. These rules are as follows:

1. Articles of faience, glass, unpainted pottery and stone, when this latter is free from both paint and plaster, may, as a rule, safely be washed and generally need prolonged soaking in repeated changes of water; in fact, faience, pottery and stone, which are all very porous and liable to contain salt, should never be wetted unless they can be soaked thoroughly, otherwise, when the object dries, any salt present will be brought to the surface where it will crystallize and cause damage.

2. Painted pottery and painted stone should not be wetted unless they are varnished or waxed, or have been protected by special treatment, that will be described later,[1] but when varnished, waxed or treated, they will bear sponging or soaking.

[1] See p. 204.

3. Articles of wood should not be wetted unless the wood is hard and in good condition, in which case, if unpainted, they may be cleaned with a damp sponge.

4. Ivory, if in good condition, may be cleaned with a damp sponge or a damp brush, but soaking should be avoided and even damping must be done with care, as old ivory is very liable to split when wet. Ivory in poor condition should never be wetted.

5. Metals may generally be washed, but should always be thoroughly dried afterwards, unless they are to be further treated immediately. In the case of metals that are dirty or corroded, washing is sometimes a useful preliminary to further treatment and is always necessary after treatment.

6. Plaster of any sort, particularly the ancient Egyptian chalk plaster,[1] unless gilt or varnished, should never be wetted, but if gilt or varnished, the surface may be cleaned with a damp sponge or damp cloth, excess water, however, being avoided, as this might penetrate below the surface to the plaster, which would be softened and destroyed.

7. Woven fabrics should not be wetted unless

[1] Termed "gesso" by Egyptologists.

they are in very good condition, in which case they may be soaked in order to remove dirt or salt.

8. Papyrus will stand a limited amount of soaking in water, but great care is necessary in handling it while wet as it is then very tender and tears readily and the ink easily rubs off.

9. If water cannot be used, or if it has been used without success, petroleum spirit (benzine, petrol) should be tried. This is applied with a small camel-hair or similar soft brush and will be found useful for painted unvarnished surfaces, when the paint is not an oil paint (for which it is unsuitable) and generally also for varnished surfaces. Unless, however, the object is perfectly dry, petroleum spirit is useless. In some cases, for example on painted unvarnished surfaces, petroleum spirit may be replaced with advantage by plain uncoloured alcohol (about 90 per cent. strength),[1] but alcohol should never be used on varnish, as resins, which are the basis of most varnishes, are soluble in this reagent. Alcohol, however, in small amount may usually be employed with safety on unvarnished oil-paint and sometimes on waxed surfaces. The brush used, either with petroleum spirit or with alcohol, should be well rinsed in the liquid each time after having been

[1] See footnote [1], p. 20.

applied to the object, and the liquid should frequently be renewed.

When water, petroleum spirit and alcohol all prove ineffectual, special treatment is necessary, the nature of which can only be known from the kind of material and the cause of any disfigurement, and no general rules are possible. A few hints, however, may be given. These are as follows:

1. Acids and alkalies should not be employed indiscriminately for the removal of deposits, incrustations and discolorations that resist the ordinary solvents and never without a certain knowledge that they will not injuriously affect the object treated, and when employed it should only be in the form of dilute solutions, every trace of which must afterwards be removed by thorough washing. The use of these reagents will be described when dealing with the various materials.

2. Attempts should not be made to scrape or chip off hard deposits or incrustations, though this is often done. Thus the corroded surface is sometimes chipped off copper, bronze and silver objects and calcium carbonate and calcium sulphate are chipped from ivory, pottery or stone. Chipping, however, except in certain cases of copper, bronze and iron that will be specially dealt with, is never satisfactory, and the object will be disfigured by scratches or even more serious damage may result.

The methods of treating incrustations will be described when dealing with the materials on which they occur.

3. Deposits and stains of an organic nature (grease, oil, resin, tar) require organic solvents to remove them, and if petroleum spirit (benzine, petrol) or alcohol [1] are not effectual such solvents as acetone, benzol or pyridine should be tried.

Two very important cautions in connexion with the cleaning of antique objects that must be observed if success is to be obtained are, first, that all cleaning processes take time, and often a considerable time, and to hurry them means impairing their efficiency, and, second, that it is necessary to learn when "to let well alone," and not to try and push the cleaning process too far, otherwise damage will be done, over-zeal frequently ending in disaster.

The next step in restoration after cleaning is repairing, and this therefore may now be considered.

Repairing

By repairing or mending is meant the refixing of loose or broken pieces, and not the addition of new material, which will be considered later. Success in repairing is a matter of manipulative skill, training, experience, patience and care. Special training in repair work and the highest

[1] See footnote [1], p. 20.

degree of manipulative skill will not fall to the lot of every one who is called upon to handle antique objects, but experience, patience and care may be acquired by all.

Repairs to antique objects are of such a varied nature that no detailed description is possible, and all that can be done is to give a few general principles, which are as follows:

1. As a general rule well clean an object before repairing it. Exceptions to this are faience glass and pottery where there is danger of the broken edges suffering during cleaning. In such cases the repairs should be done first.

2. Completely remove old cementing material before adding fresh. This should never be scraped off dry, but must first be softened. Glue may be softened by means of warm water, beeswax with turpentine, resin with alcohol, and paraffin wax with petroleum spirit (benzine, petrol) or by heat. The solvent used should be applied with a small brush and the softened cementing material wiped off with a rag or removed by means of a piece of wood or bone, such as a small paper-knife.

3. Patent or secret cementing preparations should not be used unless their general nature is known and unless their value has been well proved, and only the best quality material should be employed.

4. The manner in which the various pieces of a broken object fit together should be ascertained by careful inspection and arrangement, but, as a rule, and especially if the material is friable or easily broken, the pieces should not be put actually touching one another before applying the cement, or the edges may break further.

Adhesives

Adhesives being essential to repairing may now be considered. They are of many different kinds, but the principal ones are glue, casein adhesive, celluloid cement, and plaster of Paris, which will now be described.

Glue.—Glue is an impure gelatin, generally extracted from animal bones, skins, cartilage or tendons, but also from fish, and is one of the oldest, best known, and most reliable of all adhesives, especially for wood. It was largely used by the ancient Egyptians and in some instances, glue on objects more than 3,000 years old is still in fairly good condition.

Only the best quality glue, and of as light a colour and as free from smell as possible, should be employed. Fish glue is not satisfactory for damp climates. Glue, like every other soluble material, dissolves more quickly the finer the state of division and, therefore, should be broken into small pieces before use, which is best done by wrapping it in several folds of cloth and breaking

it with a hammer. The pieces should be placed in the glue-pot and soaked in cold water until soft and swollen, which will take several hours in hot weather and longer in cold weather.[1] The excess water should then be poured off and the glue-pot (in its water jacket) heated. The content of the inner pot (i.e. the glue) should never be allowed to boil, the maximum temperature to which it should be subjected being about 80° C. (176° F.). The best glue-pot is one made for the purpose, but where this is not obtainable, an ordinary pottery (not glass) jam-jar in a saucepan of water makes a good substitute, but it should be provided with a cover in order to diminish evaporation and so prevent the glue from thickening.

For use, glue should be fairly thin, but not too thin or watery, and it should be used hot. Thick or tepid glue should never be employed.

Glue is best applied by means of brushes, which should be of several sizes to suit different kinds of work. The brush should never be left in the glue-pot after use, but should be removed and washed in hot water.

In order to mend a broken object, the glue is evenly distributed as a thin film on both surfaces, which are then pressed tightly together and

[1] Glue absorbs about three and a half times its own weight of water.

clamped or tied with string until the glue has set, which will take at least several hours. The greater part of any glue that oozes out should be wiped off at once, but no attempt should be made to clean the surfaces thoroughly until the joint has set, when any glue still remaining should be removed with a soft rag damped with hot water.

To prevent the clamps from marking the object, the surface beneath them should be protected by thin pieces of board or cardboard. When string is used, pads of folded paper should be placed under it at the edges. A small wooden wedge under the string, or a wooden peg inserted in the string and twisted in the manner of a tourniquet, will be found useful for tightening. For some purposes, clothes pegs, of the kind provided with a spring; trouser clips, as used by cyclists; thick steel wire, with a slight spring, bent in the form of a circle with the ends (between which the object is gripped) some distance apart, or rubber bands all make useful clamps.

In addition to simple glue, certain mixtures containing glue will be found useful for special purposes. Thus, to repair broken objects of limestone, a mixture of whiting (chalk, whitening) and glue may be used instead of plaster of Paris. This is made by stirring whiting into a hot, thin glue solution until the whole becomes of the consistency

of ordinary cream. It has the advantage over plaster of Paris that it does not set so quickly and so allows more time for the adjustment of the pieces, an important matter when dealing with large objects. Before using the cement, the edges of the break should be well wetted with water.

Another cement containing glue is one sometimes employed for repairing glass and other non-porous materials that break with a smooth fracture, such as porcelain, flint and quartz. Particulars of this cement may be found in most books of household recipes, but no two of the recipes agree and many lack some detail essential for the preparation. The following may be used. Take eight grams (123 grains) of glue (or gelatine, or isinglass); soak in water until soft and swollen; drain off the excess water; warm by standing the containing vessel in hot water until the glue is melted; stir in, first one gram (15·5 grains) of finely powdered "gum" ammoniacum, [1] and then four grams (62 grains) of finely powdered mastic resin "dissolved" [2] in ten cubic centimetres (three fluid drachms) of strong, plain alcohol.[3] Put into

[1] This, although usually termed a gum, is a gum-resin.

[2] All the mastic will not dissolve, but the solution should be well stirred and all added.

[3] Not methylated spirit.

a wide-mouthed bottle while hot, as when cold it sets to a jelly. For use, warm the bottle in hot water and apply the cement hot. To avoid mould, add a few drops of a strong solution of carbolic acid. This cement is not wholly satisfactory, as it is troublesome to make and will not stand soaking in water. In this connexion it may be mentioned that Pliny (first century A.D.) states [1] that a mixture of white of egg and quicklime unites broken glass, which it does effectually.

Casein Adhesive.—Casein is the protein from milk, and for the preparation of an adhesive this is precipitated by acids, washed, dried, ground and mixed with small proportions of other materials, such as sodium carbonate, sodium fluoride or slaked lime.

Casein adhesive is frequently called "cold water glue," and is sold in the form of a fine powder, which only requires mixing with water to be ready for use. It is about equal to the best glue in adhesive properties.

Celluloid cement consists of celluloid [2] dissolved in an appropriate solvent. A satisfactory cement may be prepared by dissolving celluloid in acetone. The celluloid is cut into small fragments and put

[1] *Natural History*, XXIX, II.
[2] See p. 53.

into a wide-mouthed bottle. Acetone is then added and the mixture is repeatedly stirred with a piece of wood and finally left overnight. Sufficient celluloid should be used to make a thick syrup. By the addition of more celluloid or of more acetone the consistency is easily adjusted to that required. Since acetone is very volatile the bottle should not be left open. Cements of this nature are now on the market put up in tubes ready for use.

Celluloid cement is waterproof and is admirably adapted for repairing faience, inlay, pottery, stone, wood and most other materials. It is best applied with a small camel-hair brush and, as it does not set instantaneously, sufficient time must be allowed for complete setting before the object is disturbed.

When using the cement on a porous object, such as faience or pottery, it should be allowed to soak well in before making the joint, or preferably before applying the cement, the broken surfaces should be coated repeatedly with a dilute (1 per cent.) solution of celluloid. When dry, excess cement may be removed by means of a soft rag damped with acetone.

For repairing non-porous material with a smooth surface, such as glass, porcelain and certain kinds of stone including flint and quartz, no thoroughly satisfactory cement has yet been found. Celluloid

cement which sometimes, though not always, gives good results, possesses one very useful feature, namely that it will stand washing. The glue cement already described sticks well, but is troublesome to make and will not stand soaking in water.

As it is rarely possible to clamp articles of faience, glass and pottery while the cement sets in the manner adopted for wood, other methods of keeping the broken surfaces together must be employed. Occasionally, surgical bandages, string, thread or rubber bands can be used, but as a rule, the best way is to keep the joint in such a position until set that the weight of the material itself presses the edges together. This may be done by standing the object in sand, plasticine or the special adhesive wax used in chemical laboratories for temporarily fixing apparatus, or by supporting the repaired portion by means of plasticine applied along the joint. For light-coloured porous material, however, plasticine should not be used, as it is liable to cause staining. When sand is employed, it should be clean, fine quartz sand free from stones and dust, and should be sifted and washed before use.

Plaster of Paris.—This is employed for repairing large pottery and stone objects, and it should be of the best quality obtainable. In one case in the author's experience, a poor quality local plaster

used in Egypt seriously damaged an object with which it was used by reason of the salt present.

In order to prepare the material, take as much water in a basin as will give the required quantity of plaster and into this sprinkle rapidly and uniformly with the hand, dry plaster in fine powder. At first the powder sinks and the sprinkling is continued until, instead of sinking, it stands above the water. This gradual saturation of the plaster from below expels the air without causing bubbles, which should be carefully avoided. Beat the mixture with a spoon in such a manner that the bowl of the spoon is not brought to the surface, otherwise air is carried in and causes bubbles. Finally skim off any bubbles or scum that may have formed. The plaster, which is about the consistency of ordinary cream, should be used quickly.

It adds to the life and durability of plaster of Paris if it be treated repeatedly, when thoroughly dry, with a dilute solution of celluloid (1 per cent.) or with very hot melted paraffin wax, either by immersion or by applying the wax by means of a brush until the plaster will not absorb any more. If required, the surface after the wax treatment may be polished with French chalk (talc) and a soft cloth or a pad of cotton wool.

The setting of plaster of Paris may be hastened

or retarded by dissolving certain substances in the water used for mixing. Generally any hastening of the set is unnecessary, as the plaster sets quite rapidly enough for all the purposes required and occasionally even too rapidly. When the latter occurs, the setting may be retarded by dissolving a little gum, glue or borax in the water, all of which also harden the plaster and give it a better surface.

Strengthening

Sometimes an article, as for instance, ivory, gilt or painted plaster, wood or other object is intact, inasmuch as there are not any parts missing, but it is in such a fragile and delicate condition that it cannot be handled without falling to pieces. In such a case, the object manifestly must be strengthened if it is to continue to exist. The only manner in which this can be done is by impregnation with some substance that will consolidate it, which must be applied in the liquid form in order to obtain penetration. One of the most valuable of such substances is melted paraffin wax or beeswax, and another is a solution of celluloid.

Wax is used in the melted condition and very hot and the object should be thoroughly dry, so that the wax may soak well in and not congeal on the surface, and the operation should be carried out in a warm place. For small objects immersion

in the melted wax and allowing them to remain until all the air is expelled, then removing and draining them is, as a rule, satisfactory, but the object should, if possible, be warm before immersion, in order to avoid too sudden a change of temperature, and should be free from blisters or other large air spaces, otherwise the imprisoned air in expanding and escaping will cause rupture. Immersion, too, should be gradual, so that the air may more easily escape. Another very satisfactory manner of treating small objects is to apply the wax by means of a pipette, one of about 10 c.c. capacity being a useful size. The pipette should be placed quite close to the surface of the object and the wax, which should be very hot, should be allowed to run out as quickly as possible. The use of a pipette, although a little difficult at first, is soon learned and with care there is not any danger of drawing hot wax into the mouth, which, even if it does occur, is not hurtful, although disagreeable, as the moisture of the mouth prevents the mucous membrane from being burned. A third method of treatment is to apply the hot wax with a paint brush, one of hog bristles, as used by house painters, being the best.

For large objects the wax must either be painted on or poured on from a vessel with a spout, such as a small metal can or teapot. A spray of any

sort is a mistake, as the wax cools quickly and does not penetrate the object.

If the temperature of the object and of the wax is satisfactory, the wax sinks well in without leaving any excess visible, but otherwise some of it congeals on the surface. Excess wax left in hollows and corners, or as drops at the edges, should be wiped off with a soft rag while still liquid. The last trace may be made either to sink in or to run off, or may be liquefied so that it can readily be wiped off, by carefully warming the object in an oven or before a fire or electric radiator, or by slowly moving over it from the top downwards, almost but not quite touching the surface, a hot spatula, a hot soldering iron, or an electric heater, such as one of the elements of an electric radiator mounted in a light wooden handle. If the object is gilt, excess wax may usually safely be removed either by means of a plumber's small blast lamp fitted with a metal baffle plate so that the flame does not come into contact with the object,[1] or with a small bunsen lamp.

[1] For use with gas, Mr. Noel Heaton devised a special burner fitted with projecting rods terminating in small rollers, thus keeping the heating surface parallel to the object and at a uniform distance from it (Noel Heaton, "Encaustic Treatment of Tempera Painting in the Chelsea Town Hall, 1914," *Papers of the Society of Mural Decorators and Painters in Tempera*, II, 1907–14 (1925), p. 75.

The four gilt wooden shrines from round the sarcophagus of Tut-ankhamūn, which had a surface area (counting both sides) of about 2,660 square feet [1] and which had been consolidated with wax at Luxor, were freed from the excess wax in Cairo by the author by means of small electric heaters, using soft cotton waste to wipe off the melted wax. Parts of the roof sections of the two larger shrines, which were covered with black resin varnish in place of gilt, needed special care, as strong heating would have blistered the varnish. Paraffin wax, however, cannot always be removed safely from a varnished surface by heat, and in such a case it should be taken off with petroleum spirit (benzine, petrol) and a soft cloth.

In field work, paraffin wax is almost indispensable for consolidating objects sufficiently to enable them to be packed and transported in safety. It was first employed for this purpose by Petrie and its use has now become general. At Ur, the copper statues in the round of standing bulls ; the copper reliefs of bulls from a frieze and the mosaic columns discovered by Woolley were all first consolidated by him with hot paraffin wax, then wrapped in waxed bandages and afterwards in sacking dipped

[1] On the outside of the outermost (largest) shrine there was a considerable amount of blue faience, which was treated in the same manner as the gilt.

in glue or backed with plaster of Paris.[1] Sometimes wax treatment in the field renders the subsequent laboratory cleaning extremely difficult or may even make it practically impossible, as the wax can never completely be removed, and when this is likely to happen, some other method of consolidation should be adopted. Thus when wax would have complicated the later treatment, Woolley substituted a thick layer of glue and glued canvas.[1] Paraffin wax may be used for bone, horn, ivory, plaster and wood, most kinds of wood, however, except ebony, being considerably darkened in colour.

It should not be forgotten that ordinary paraffin wax is not of definite composition, but is a mixture of various, though related, substances possessing different melting-points, that may range from about 40·5° C. (105° F.) to about 71° C. (160° F.),[2] and that in consequence it has not a sharp melting-point, but begins to soften at a temperature much below that at which it melts. Only wax, therefore, from which the lower melting-point fractions have been removed, as far as possible, should be used, otherwise it will soften during the summer or in

[1] H. R. Hall and C. L. Woolley, *Ur Excavations, I, Al 'Ubaid,* 1927, pp. 84–7; 101–2.

[2] These are the melting-points of the qualities at present on the market.

a hot climate, but even the most carefully prepared material still contains small proportions of the lower members of the series and hence softens at a temperature well below its melting-point.

Paraffin wax is colourless, damp-proof, and one of the least alterable of organic compounds known, few chemical reagents having any action upon it, and there seems no reason why it should not last unchanged for ever, which makes it a highly satisfactory material for use on antiquities.

Beeswax has a definite melting-point that varies from about 60° C. (140° F.) to about 65° C. (149° F.) and, unlike paraffin wax, it remains hard until the melting-point is reached. For this reason it is much to be preferred to paraffin wax for many purposes, though its colour makes it objectionable for use on white or light-coloured material, such for example as white plaster, a difficulty, however, that may be overcome by using bleached wax. Beeswax is not so highly unchangeable as paraffin wax and it may eventually disintegrate on the surface, or when it is present in thin layers, owing generally to oxidation, though occasionally to mould,[1] but it often lasts in good condition for several thousands of years and when disintegrated

[1] J. J. Dobbie and J. J. Fox, The Composition of some Mediaeval Wax Seals, *Journal, Chemical Society,* cv (1914), pp. 795–800.

on the surface it may readily be restored to its original appearance by suitable treatment.

In this connexion the cleaning and preservation of objects of beeswax may briefly be dealt with. Jenkinson [1] cleaned seals of beeswax and resin with soap and water and a very soft brush; he restored perished (flaky) seals by means of a solution of beeswax in a mixture of turpentine and petroleum spirit (benzine, petrol) and he repaired broken seals with a mixture of beeswax (2 parts) and resin (1 part), applied warm and worked in with a hot knife or bodkin, using spirit varnish (sandarac or shellac) for the preliminary holding together of small pieces and pins to obtain extra strength.

In the case of two beeswax objects more than 3,000 years old, the surface of which was slightly disintegrated, the author was able to restore the original appearance by the use of chloroform applied with an artist's camel-hair brush. The author has also successfully cleaned ancient inscribed wax tablets by means of alcohol applied with a small soft brush. Scott treated two wax tablets, that had inadvertently been left in the sun, which had melted the wax, by "careful

[1] Hilary Jenkinson, Some Notes on the Preservation, Moulding and Casting of Seals, *The Antiquaries Journal*, IV (1924), pp. 388–403.

scraping with a razor blade, followed by gentle rubbing with a small pad of cotton-wool moistened with petroleum ether." [1]

Celluloid is employed in dilute solution in a mixture of equal parts of acetone and amyl acetate,[2] which is either sprayed on the object or applied with a small soft brush and is especially useful for bone, ivory, painted surfaces and stone. A satisfactory form of small spraying apparatus is an atomizer as used for the throat. For a large spray, one such as is employed with insecticides may be used. All sprays should be of simple construction, so that they may readily be taken to pieces and cleaned and they should be emptied and washed out with acetone each time after use. One drawback of a large spray is that it gives so strong a current of air that if used on surfaces from which the paint is peeling, fragments of this may be blown off and in such cases one or two coats of celluloid should first be applied with a brush and the work then continued with the spray.

An excess of celluloid (i.e. either too strong a solution or too many coats of a dilute solution)

[1] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, Third Report, 1926, pp. 10–11.

[2] See pp. 53–4.

on certain painted objects, especially tempera paintings on clay plaster, may cause the paint to crack and to become raised up in small saucer-shaped fragments over the whole surface, this being brought about by the contraction of the celluloid on drying.

Renewing

This is the addition of new material to replace parts of an object that are missing.

Renewals are sometimes absolutely necessary, as an object may become so unstable and insecure that additional material must be added for strengthening purposes if absolute ruin is to be prevented. There is, however, a great difference of opinion as to what extent renewals are permissible, and no general rules can be laid down, but each case should be decided on its own merits.

It is often stated as a principle of good conservation that only such additions of new material should be made as are required for permanent stability. This is supported by the argument that a broken or decayed original object, if safe from further disintegration, although possibly not so pleasing from an artistic standpoint, is considerably more valuable from the archæological or historical aspect than the most perfect of new work. Although as a general principle this may be perfectly sound, if always carried out in practice, it would sometimes result in an object being left

in such an incomplete condition that its original shape and purpose would be obscure.

In the author's opinion the object should be made to look as much like the original as possible and, although the restoration should not be too conspicuous, there should always be sufficient difference in material or colour to be seen when closely examined. Thus, for example, if the missing parts of a vase or statue are replaced by plaster of Paris, this should not be left white and ugly, but should be tinted almost, but not quite, the colour of the original.

Whatever view, however, is taken regarding renewals, there can be no doubt that all original parts of an object should be preserved and that a detailed descriptive and photographic record of the exact condition of the object before it was treated should be made.

CHAPTER II

PRESERVATION

The cleaning, repairing and strengthening of antique objects all help towards their preservation, but this treatment, useful and necessary as it is, is not sufficient, and merely to treat an object and then to put it in a museum and expect it to remain unchanged is unreasonable, and in many cases the object would last longer if left buried in the tomb. The principal dangers that require to be guarded against are light, moisture and other atmospheric influences, dust, insects, bacteria and fungi. These will now separately be considered.

Light

The destructive effect of direct sunlight on colours is so well known that it is customary in ordinary households to draw down the blinds of a room exposed to the sun in order to prevent the fading of curtains, carpets and wall-paper. Not only, however, does sunlight cause certain colours to fade, but it also causes articles, such as textile fabrics, paper, papyrus and wood, to become discoloured and tender.

Diffused daylight is also injurious, though to a less extent than direct sunlight, and even artificial light is not without effect, darkness in most cases being the only complete protection. Since, however, museum exhibits cannot be kept in darkness, the practical remedies are to exclude direct sunlight and to minimize the effects of reflected light when this is too strong by the use of blinds or curtains to the windows or by covers or curtains to special show-cases containing objects that are particularly susceptible to light, except when these are actually being used.

With respect to the best colour for blinds and curtains the matter is not so simple as it might appear, since there are a number of different factors to be taken into account, the most important of which may now be considered.

The exclusion of light by a woven fabric depends upon its closeness of texture and its thickness and not upon the colour, and, so far as light only is concerned, the colour is of no consequence, all colours excluding the light equally well, other things being alike. If, therefore, the light effect of sunlight were the only point to be considered, the choice of colour would depend upon the appearance and cost of the material. But there is another important factor to be allowed for,

namely, the temperature effect of sunlight, different-coloured materials varying considerably in their absorptive power for heat, black having the highest heat capacity and white the least. Hence, since all colours exclude sunlight equally well, if the texture and thickness of the fabrics are alike, but since dark-coloured fabrics absorb and transmit more heat than light-coloured fabrics, the former are manifestly to be avoided and the latter chosen. But although white is the best of all colours from a temperature point of view, it may be objected to on æsthetic grounds, or it may be desirable for economical reasons to have a colour that does not show the dirt so easily, and in such cases yellowish tints (yellow, khaki or yellowish-brown) should be chosen.

Instead of blinds or curtains, coloured glass might be employed, but would be more expensive. As glass (unlike cloth) is transparent or translucent, it is the colour transmitted and not that reflected that is important, and since the blue and violet rays of light are chemically the most active and hence the most injurious from a museum point of view, glass of these colours should be avoided: red, too, which transmits more of the heat rays should also be avoided, the most satisfactory colours being those near the middle of the spectrum, namely, the yellow tints.

Moisture and other Atmospheric Influences

Many of the influences destructive of antique objects cannot operate in the absence of moisture. Thus moisture is essential to the life of bacteria and fungi, to the action of salt, to many chemical changes, and probably to the fading caused by light. Moisture is also injurious on account of its solvent action on various materials, more particularly when it contains, as it practically always does, carbon dioxide derived from the air, and still more if it contains, as may happen, sulphur acids from the burning of coal or coal gas. The exclusion of moisture-laden air therefore is essential. This can be done by proper attention to heating and ventilation and by the use of museum cases in which the air having access is filtered through a drying agent such as calcium chloride, or by the use of calcium chloride inside the cases. If a drying agent is employed it is necessary that it should be kept in suitable receptacles, and that it should be renewed frequently, otherwise more damage may be caused than by its omission. For some objects, such as mummies, the atmosphere of the case should be as dry as possible, but for other objects an absolutely dry atmosphere (which, however, would be difficult to obtain) is not desirable, thus wood, when quite dry, contracts and cracks, and any plaster or paint on the surface breaks off.

Among injurious atmospheric influences may be mentioned too high a temperature and too great a range of temperature, and as equable a temperature as possible should be obtained.

Dust

Dust is objectionable, not so much on account of any direct damage it causes, although this may happen, but more especially because its presence necessitates constant handling of the objects in order to clean them. The remedy against dust is to use dust-proof cases.

Insects

Organic materials of almost all kinds are liable to be attacked and even utterly destroyed by insects which comprise the larvæ of various kinds of beetles and moths; the silverfish insect; cockroaches and white ants; and they consume feathers, fur, hair, horn, ivory, leather, mummies, skins, wood, wool, and many other materials.

There are two ways of combating insect pests: first, to prevent their access to the materials liable to be attacked; and second, to kill them should the articles, in spite of all precautions, be invaded.

The best preventive measures are well-fitting show-cases, frequent inspection, and periodical cleaning, and, for such articles as feathers, fur, hair, skins and wool, the keeping of paradichlorbenzene (a white crystalline solid), naphthalene (flakes) or thymol in the cases, none of which,

however, ensures more than a limited protection against certain kinds of insects.

The best cure for materials that are attacked is fumigation, either with carbon disulphide or with a mixture of ethylene dichloride (3 parts by volume) and carbon tetrachloride (1 part by volume), the latter being added to make the material non-inflammable. These are liquids that on exposure to the air evaporate, forming gases that are very effective insecticides. The simplest and most satisfactory method of using them is to leave them, contained in suitable receptacles, exposed for several days in the upper part [1] of the show-case in which are the articles to be treated, or to remove the articles to a special air-tight case in which the fumigation may be carried out.

Liquid carbon disulphide is very inflammable and very volatile and the vapour is also very inflammable and when mixed with air in certain small proportions is also explosive ; it must therefore be used with all necessary precautions and fires, naked lights and smoking in the vicinity must be avoided. Carbon disulphide, too, has a

[1] The gases are heavier than air. Leechman (D. Leechman, *Technical Methods in the Preservation of Anthropological Museum Specimens*, 1931, p. 136) recommends 0·8 pounds weight of carbon disulphide or 1·4 pounds weight of the ethylene dichloride and carbon tetrachloride mixture for each 100 cubic feet of space.

very objectionable smell, but this soon disappears from the objects treated. The ethylene dichloride and carbon tetrachloride mixture is non-explosive and non-inflammable.

Other preventives and remedies are to spray the material with (*a*) petroleum spirit (benzine, petrol), (*b*) a solution of paradichlorbenzene in carbon tetrachloride, or (*c*) a solution of naphthalene in carbon tetrachloride. Arsenic compounds and copper compounds, which are excellent insecticides, should not be used for antique objects, as they can only be employed in solution in water, and water is generally to be avoided. This subject will be dealt with further when the separate materials are being considered.

Bacteria and Fungi

Among the agents of destruction that gain access to antique objects and damage or destroy them, are bacteria and certain vegetable growths such as lichens and fungi (moulds). Thus, for example, bacteria attack mummies, lichens disfigure stone and old window glass, also aiding disintegration, and fungi damage mummies, paper, papyrus, plaster, woven fabrics and wood. These agents all need moisture and warmth for their development, and although warmth cannot be avoided, objects can with care be kept dry. The treatment of objects attacked will be described when the objects themselves are being considered.

Handling

When dealing with antique objects it should not be forgotten that the human hands, even when clean, are always more or less moist and greasy, and that perspiration contains acid bodies and salt. In a hot country the effects of acid perspiration are very noticeable, and in the summer in Egypt, for example, blue litmus paper held in the fingers is reddened. Metal and other objects susceptible to the action of moisture, acids and grease should therefore be handled as little as possible, and the hands should be covered with white cotton gloves or with a cloth.

Preservative Coatings

Although an object may have been cleaned and restored, it is, as already mentioned, constantly subject to agencies such as atmospheric influences and contact with the hands, that tend to injure and destroy it. One of the means adopted to protect objects from these influences, is to coat them with some preservative that is impermeable to moisture and acid. In everyday life a common preservative is oil-paint or varnish, and in museums linseed oil is sometimes used to protect bronze and iron objects, and occasionally ordinary painter's varnish is used for bones. All these substances, however, are too crude and too disfiguring to be employed on objects of art, and fortunately there are excellent substitutes that are colourless. Among these, one stands out as much superior

to the rest, namely, a solution of celluloid in acetone or in a mixture of equal parts of acetone and amyl acetate. Acetone, being more volatile than amyl acetate, dries the sooner of the two and generally too quickly in the summer or in a warm climate to give satisfactory results, and on this account the mixed solvent is to be preferred for most purposes.

In order to make the solution, the best quality and the purest materials only should be employed. Transparent celluloid of the kind used for motor-car side screens [1] is cut into small pieces and 10 grams (154 grains) weighed out and placed in a bottle having a capacity of rather more than half a litre (approximately 1 pint); 250 c.c. (9 fluid ounces) of acetone are added and the bottle shaken until all the celluloid is dissolved; 250 c.c. (9 fluid ounces) of amyl acetate are then added and the mixture well shaken. This makes a 2 per cent. solution, which is too strong for ordinary use and it should be diluted down to 1 per cent., which may be done by taking a measured portion,

[1] The amount of celluloid required is so small and the cost of the best quality is so slight that there is no excuse for using old photographic films, as is sometimes recommended, apart from the facts that such films must be freed from their gelatine coating before use, and that they are almost certain to be contaminated permanently with the reagents that have been employed for developing.

say 100 c.c. (28 fluid drachms) and adding to it 50 c.c. (14 fluid drachms) of acetone and 50 c.c. (14 fluid drachms) of amyl acetate and well shaking. The solution is colourless and, unless used too strong, or in too great a quantity, it does not impart any gloss to the objects treated. Excess of celluloid may readily be removed with acetone and a soft rag.

Other varnishes that may be mentioned are (*a*) a dilute solution of dammar resin (generally, but incorrectly, called "gum" dammar) in benzol or petroleum spirit (benzine, petrol); (*b*) a dilute solution of mastic resin in alcohol[1]; and (*c*) a dilute solution of bleached shellac in alcohol.[1] These solutions should be used in about 5 per cent. strength; none of them is colourless, but all are slightly yellow.

[1] See footnote [1], p. 20.

CHAPTER III

APPLICATION OF METHODS TO SPECIFIC MATERIALS

The application to specific materials of the methods already outlined will now be described, the materials being treated in alphabetical order.

AMBER AND OTHER RESINS

Amber

Since amber is a fossil resin any particular piece from a tomb must have been buried for geological ages before it was found and used by man, and therefore burial for a few thousand years more has generally little or no effect, and it is usually in good condition, though sometimes dirty. It is best cleaned by careful washing with good quality soap and warm water, aided by gentle rubbing with the fingers, followed by rinsing in clean water and drying without artificial heat.

Other Resins

Resins, other than amber, are often very brittle, and may be too tender to bear much treatment. Washing in warm water or cleaning with a damp camel-hair brush may however be tried, but should

not be persisted in unless it is manifest that no harm is being done.

Organic solvents (alcohol, acetone, benzol) should on no account be employed for cleaning, as many of them soften and dissolve resins. This solvent action may be utilized if, as sometimes happens, the surface of resin beads, or other resin objects, is disintegrating and flaking off. In such cases the object should be gently brushed over with alcohol or acetone, either of which will cause the loose surface to become sticky and to adhere again.

Resin objects may be repaired with celluloid cement, or in the case of objects of resin other than amber (amber being too insoluble), by moistening the broken surfaces with alcohol or acetone and then pressing them together.

In connexion with resin, the black varnish-like coating on many wooden funerary objects from ancient Egypt, which is so often wrongly termed bitumen, pitch or tar, may be mentioned. This material is a black resin, possibly such as is found and used in India, China and Japan at the present day. It was usually applied directly to the wood and is often now not very adherent, but tending to flake off. Being a resin, it is soluble in such reagents as alcohol and acetone, and if sprayed, or otherwise treated, with these solvents it softens and adheres again. This treatment usually makes

the surface very glossy and is sometimes objected to on that account, but in most cases this was the original appearance.

Baskets, Cordage and Matting

Vegetable fibres, such as grasses, reeds, rushes and sedges have been employed from very early times for making baskets, boxes, brushes, cordage, matting, sandals and other objects. Such articles become very dry and brittle with lapse of time, but otherwise are generally in a fairly good state of preservation.

If the condition of the object will allow, superficial dust and dirt may be removed by gentle blowing with a small pair of bellows or careful brushing with a small soft brush. In the case of very fragile objects, the careful application of petroleum spirit (benzine, petrol) or alcohol with a small camel-hair brush will be found helpful for cleaning, and a brush thus moistened may often be used when a dry brush would cause damage. Water, as a rule, should not be used.

Objects of the kind under consideration may be strengthened and preserved by saturating them with melted paraffin wax. The material, being absorbent, takes the wax well, and if this is applied quickly and very hot no excess will be visible on the surface. The colour will be dark-

ened somewhat, but the result is not unpleasing, and the object will be firm and will last indefinitely. Excess wax may be removed by warming, either in the sun or before a fire or electric heater.

Beads and Beadwork

Beads Beads are of so many different kinds and vary so much in the material of which they are made, that no general directions for treatment can be given.

Most beads, with the exception of those of wood or resin, will stand washing with soap and warm water. Solid gold beads, after washing, may be further cleaned, if necessary, with ammonia or by heating.[1] Gilt wooden beads, unless in bad condition, may be cleaned with a soft brush or cloth moistened with dilute ammonia, but should only be damped and not soaked, or the gilt (which in ancient Egyptian gilt beads is fastened on with glue) may be removed. Resin beads may be cleaned with a damp brush.[2] Beads of Egyptian faience often need well soaking in repeated changes of water in order to remove salt.[3]

The holes in beads may be freed from dirt and old thread by means of a piece of thin wire for the larger and more solid ones and with a stiff bristle for the smaller and more fragile ones. A thin needle mounted in a wooden handle and made

[1] See p. 109. [2] See p. 55. [3] See p. 64.

red hot in the flame of a small spirit lamp will often be found useful. In cases in which the hole is solidly blocked and the blocking material is hard, great care and patience are needed, otherwise the edges of the hole will be chipped or the bead split. Generally the holes should be cleaned before the beads are wetted, as water frequently causes the obstructing material to swell and so to become more difficult to dislodge, though occasionally the reverse is the case and the stopping becomes softened and loosened by soaking in water.

Beadwork

Beadwork when found is often in a very fragile condition, on account of the material on which the beads were sewn or the thread used having perished. In such cases it may be consolidated by treatment with melted paraffin wax, though this will darken and spoil the appearance of any fabric to which the beads may be attached. If the wax is required to soak well in, it should be applied very hot, but if much penetration is undesirable, as likely to cause the beads to adhere to objects below, the wax should be almost on the point of solidification before use. Excess wax may be removed by heat.

Clay

Only unbaked clay will be considered, baked clay being dealt with as pottery. Clay objects

include moulds, sealings, small animal and human figures and inscribed tablets. As clay falls to pieces when wetted, therefore it cannot be washed. After removing superficial dust and dirt by blowing or brushing, clay objects if possible should be hardened by baking. The fact that the appearance is altered somewhat and the colour changed should not as a rule be allowed to stand in the way of treatment, as the life of dried clay is very short and baking is the most satisfactory method of prolonging it. With a little experience or by means of preliminary experiments, aided by Seger cones or pyrometers, the best temperature and the necessary time for the baking can be found within narrow limits. Too great a temperature and too sudden a rise of temperature should be avoided. For small objects a gas or electric muffle furnace similar to those used in chemical laboratories will be found satisfactory. Any crystals of calcium sulphate on the surface will be dehydrated and will fall to powder during baking.

After baking, clay objects, if necessary, may be soaked in water to remove salt or may be treated with dilute hydrochloric acid to remove concretions of calcium carbonate. If acid is used, the objects must afterwards be soaked in repeated changes of water until on testing no trace of this remains. The object is then slowly but thoroughly dried.

Clay objects that cannot be baked, or that it is not wished to bake, may be strengthened by repeated applications of a dilute solution of celluloid (1 per cent.), a method that has been applied with very satisfactory results to sealings; fragments of painted clay plaster removed from mud brick walls; figures and other clay objects.

Broken objects may be repaired either with celluloid cement or with plaster of Paris suitably tinted. Missing parts may be replaced by tinted plaster, which is treated when quite dry with celluloid solution or with hot melted paraffin wax, as already described.

Egyptian Faience

This consists of a highly siliceous body coated with glaze, that is to say it is a glazed frit. It is generally coloured, often being blue or green, though it may be almost any colour.

The glaze of faience is particularly liable to disintegration. Occasionally there is a cracking and partial peeling of the whole depth of the glazed surface, leaving bare patches of the body material exposed. This is caused by a different rate of expansion and contraction between the glaze and the body. There is no remedy, but fortunately it is not progressive, and patches only of the glaze fall off. When the pieces of fallen

glaze exist they may be cemented in place again with celluloid cement. As a rule it will be found that the pieces are larger than the place from which they have fallen, owing to the body having contracted or the glaze having expanded, but with care they may be adjusted to fit by means of a small file or with fine emery paper.

Generally the decomposition of faience takes the form of a disintegration of the glaze accompanied by a white crystalline deposit on the surface. This deposit is ordinarily highly siliceous and frequently contains small proportions of sodium carbonate, common salt and sodium sulphate. The sodium carbonate is formed from the alkali of the glaze and the carbon dioxide of the air, and any common salt or sodium sulphate present originates in the natron used for making the glaze, in which both occur as impurities. This disintegration is very unsightly, and results in the destruction of the surface and the disappearance of the colour. Sometimes, however, the colour disappears or changes without any signs of disintegration of the glaze; thus blue may become green or fade to white, and green may turn brown.

The phenomena described are manifestly caused by chemical decomposition having taken place in the glaze. The agent responsible is principally moisture, the mechanism of the action being

probably much as follows. The glaze is porous and contains a large proportion of alkali combined in the form of silicates, that are readily acted upon by water; moisture condenses on the surface and is absorbed; this decomposes the alkaline silicates setting free both alkali and silica, the former of which combines with carbon dioxide from the air with the formation of sodium carbonate, the final result being a disintegration of the glaze with the deposition of the products of decomposition on the surface, sometimes in the form of a white or slightly tinted loose film, which eventually scales off or may be removed by brushing or abrasion, but more often as a white coating of which only a small part can be removed, the greater part consisting of strongly adherent crystalline siliceous material. Concurrently with this disintegration the pigment of the glaze may undergo chemical change and, as already stated, blue may become green or white, and green may turn brown. Frequently, however, much of the colour is merely obscured and not destroyed.

Although the glaze of faience is essentially glass, it is much more subject to disintegration than glass, possibly because it contains a greater proportion of alkali or because it has been fused at a lower temperature and therefore is more porous, and may contain common salt and sodium sul-

phate, derived from the natron used in the manufacture, both of which would disappear at a higher temperature.

In addition to the disintegration described, which is largely chemical and from within, although initiated and aided by outside influences, there is another form which may occur which is wholly physical and from without. This is confined to objects that have been in contact with salt and that have been alternately wet and dry. In this case the faience, which is very porous, becomes impregnated with a solution of salt, and when the object dries, the salt is brought to the surface by capillary attraction, and as the water holding it in solution evaporates, the salt crystallizes, and by the mere act of crystallization forces off particles of the glaze.

The best method of treating faience is as follows :

1. Wash well with warm water and soap, using a small sponge or soft brush. This removes superficial dirt.

2. Soak well in repeated changes of water until free from common salt and sodium sulphate. Gently boiling the water will help by the mechanical stirring set up, but boiling water has no great advantage over warm water as a solvent for common salt, though it helps the solution of sodium sulphate. When in the water the colour

of the glaze will appear very bright, and any white surface deposit will hardly be visible.

3. Dry thoroughly but slowly, and at not too high a temperature. The result will be disappointing, since any white deposit, in so far as it consists of siliceous material, will now be apparent again and will obscure the colour of the glaze.

4. If there is still a white or tinted film on the surface, brushing with a small hard brush or rubbing with very fine emery paper should be tried. Occasionally much of the film may be removed in this way, though more frequently the treatment is without effect. Rinse well in water and dry thoroughly. The drying is very tedious and may take several days, but it is essential that the object should be "bone" dry before being waxed, otherwise there would be danger of the glaze being forced off by the escaping steam.

5. Warm.

6. Immerse in very hot melted paraffin wax or paint over with very hot wax; wipe off surplus wax while still hot and polish with a soft cloth. The white deposit will become almost invisible and the original colour will once more be seen, as was the case when the object was soaking in water. Olive oil and poppy-seed oil have both been recommended for a similar purpose, but paraffin wax is the most satisfactory.

The explanation of the action of the wax or oil is that the white appearance of the faience is due to the scattering of the reflected light from the innumerable irregular surfaces of the crystalline deposit, but when the air is removed and replaced by a substance, such as one of those mentioned, the refractive index of which is approximately that of the material itself, the crystals become almost transparent and the colour of the glaze underneath is seen through.

The use of acid, caustic soda, or sodium carbonate for cleaning faience is unnecessary and is not recommended, partly because these reagents tend to act upon the glaze and to destroy it, and partly because they are very difficult to remove afterwards, even by repeated washing.

Great care is necessary in handling faience pendants, as the eyehole is easily damaged. When the projecting piece containing the eyehole breaks off this may be refastened in place with celluloid cement, but if the eyehole itself breaks the best remedy is to make a fresh one by cementing on a small bead of the requisite colour.

Broken faience is best repaired with celluloid cement. Missing parts may be replaced by plaster of Paris, the broken edges being wetted before the plaster is applied. When the plaster is well set, but not too hard, the surface should be smoothed

with very fine glass paper and when quite dry (which will not be for several days) it should be painted with very hot paraffin wax.

Feathers and Hair

Feathers become very tender and brittle with age and on this account old feathers cannot usually be cleaned, but they may be strengthened by spraying them with a very dilute solution of celluloid (0·5 per cent.). Care must be taken that the liquid is delivered in the form of a very fine spray and that the feathers do not become saturated with the solution, otherwise the finer portions will stick together and the appearance will be spoiled. **Feathers**

Hair is very resistant to ordinary influences of decay and as a rule will not require treatment, except occasionally the removal of grease, which may be done by soaking it in several changes of ether or of a mixture of alcohol [1] and ether. The use of alkalies, such as soda or ammonia, should be avoided, as these destroy hair. **Hair**

Both feathers and hair are very liable to be attacked by insects, and, therefore, they should be kept in cases that will exclude these pests; they should also be examined periodically and thymol or naphthalene (flakes) should be kept in the case, although these are only a limited pro-

[1] See footnote [1], p. 20.

tection against certain kinds of insects. If actually attacked by insects, feathers and hair should be fumigated in the manner already described.[1]

Glass

Glass is not the unalterable impermeable material generally supposed. This is especially true of ancient Egyptian glass, which is softer, and was originally softer, than modern glass, on account of its containing a much larger proportion of alkali.

The decomposition of glass is sometimes not more than a slight dimming of the surface, but more generally small particles scale off leaving the surface pitted, or the whole surface may crack and scale. This latter condition is often accompanied by an iridescence, which is purely an optical effect produced by the breaking up of the white light as it is reflected from the numberless small colourless scales that result from the decomposition. Occasionally ancient Egyptian glass may become so rotten that it falls to pieces when touched, but fortunately this extreme form of disintegration is very rare.

Apart from the chemical decomposition of the glass itself, the colour often undergoes change. Thus white glass of ordinary quality containing manganese compounds becomes coloured when

[1] See p. 50.

exposed for some time to strong sunlight. This colour varies from a very slight to a deep amethyst colour. In Egypt it is a matter of common observation to find in the desert, in the neighbourhood of towns, pieces of what has been white glass coloured in this manner. The depth of the colour appears to depend upon the time of exposure. Other colour changes may also occur in glass, for example, the blue colour of old Egyptian glass, when this is due to copper compounds, sometimes changes to green or fades to grey, and red glass becomes covered with a green coating. The colours of stained-glass windows, too, undergo slight changes of tint as the result of long exposure, which, however, generally mellow them and add to their beauty.

The decomposition of ancient glass is primarily due to the fact that such glass contains an excess of alkali, and, as glass is hygroscopic and collects on its surface moisture from the atmosphere containing carbon dioxide in solution, the result is a chemical decomposition of the glass accompanied by the formation of sodium carbonate and the separation of siliceous material. In the case of mediæval window glass, secondary corrosion due to the growth of lichens often follows the original weathering.

If glass is in good condition, no treatment is

usually required beyond washing in warm water with the aid of a little soap, rinsing in warm water and drying with a soft warm cloth.

When glass is badly disintegrating, it frequently shows on the surface either a crystalline efflorescence that is alkaline or drops of alkaline liquid. In such a case it should be immersed for a short time in a dilute solution of sulphuric acid (1 part of strong acid to 99 parts of water), stood on a clean cloth to drain, immersed in alcohol for a few minutes, allowed to dry and coated repeatedly with a dilute solution of celluloid or of one of the varnishes already described,[1] or with hot, melted paraffin wax. This coating is essential, as unless the glass is protected from atmospheric moisture, disintegration, although temporarily arrested, will re-commence. A drying agent should be kept in the case with the glass. Glass may be repaired either with celluloid cement, or with the special cement already described,[2] neither of which, however, is wholly satisfactory.

Ivory, Bone and Horn

Ivory The condition of ivory objects as found varies considerably, some being in a very good state of preservation, while others are so brittle as to make

[1] See p. 54. [2] See pp. 30–1.

even handling difficult, and many ivory objects from Egypt, in consequence of containing salt, are particularly fragile.

When in good condition, ivory may be cleaned by means of a damp sponge or damp brush, but it should not be wetted much as it is very liable to split or small splinters may fly off. Occasionally, however, ivory, and even the most ancient ivory, may be soaked in water without damage, and this treatment is often very desirable in order to remove salt, but it cannot be adopted as a routine practice, owing to the uncertainty of the results. Although the appearance and condition of an object are some guide to its probable behaviour in water, it is generally impossible to be certain beforehand that a particular piece of ivory will stand soaking, and the safe rule, therefore, is to avoid water. In the exceptional case in which the risk is taken and an ivory object is soaked in water it should afterwards be soaked in alcohol and then slowly dried without artificial heat. As a measure of precaution the object should be wrapped tightly in fine gauze or bound closely with fine string or with thread before soaking.

After cleaning, ivory may be strengthened by brushing over repeatedly with a dilute (1 per cent.) solution of celluloid. Even using a dilute

solution a slight glaze may be produced, but this is not objectionable, and gives the effect of the polish usually seen on ivory objects, but much glaze should be avoided. Excess glaze may be removed by means of acetone applied on a tuft of cotton-wool.

For ivory in bad condition there is only one remedy, namely, impregnation with celluloid, or melted paraffin wax, and this must be done without any attempt being made to remove any salt present. Before treatment the object should be cleaned as well as possible by gentle blowing and brushing, followed by further brushing with a small soft brush damped with alcohol. Sometimes the alcohol will loosen adherent earthy matter, which may thus be removed. The object is then slowly dried and, if celluloid is used, this is applied in the form of a 1 per cent. solution with a small camel-hair brush. If wax is employed, the object previously warmed, if possible, is placed on supports in order that it may drain, and is treated, first on one side and then on the other, with hot melted paraffin wax. The wax should be applied quickly by means of a pipette or small brush. If the temperature of the object and of the wax are both satisfactory, the wax sinks well in without any being visible on the surface. If, however, excess wax is left, this may be removed in the

manner already described. One objection, though not a serious one, to the use of paraffin wax is that it may slightly darken the ivory.

Not infrequently ivory objects found in Egypt are coated with a hard incrustation of calcium carbonate, or of sand and earth cemented together by calcium carbonate. This can only be removed by the use of acid, hydrochloric acid being recommended. The acid should be very dilute (5 parts of strong acid to 95 parts of water) and is best applied by brushing it repeatedly over the incrustation by means of a camel-hair brush. After treatment, it is essential that every trace of acid should be washed out by soaking the object in repeated changes of water until on testing the washings are found to be acid free. It is, however, only ivory in an exceptionally good state of preservation that will stand such treatment.

The ivory objects found by Layard at Nineveh were consolidated by soaking or boiling them in a solution of gelatine, which is stated to have given satisfactory results.[1, 2] Any such treatment would be quite unsuitable for most ancient Egyptian ivory and would end in disaster on account of the water present with the gelatine. The penetration, too, would be very slight and

[1] A. H. Layard, *Nineveh*, II, 1854, p. 9.

[2] W. Maskell, *Ivories, Ancient and Mediæval*, 1875, p. 6.

the gelatine would remain on the surface, where it would become mouldy.

The gelatine method of removing salt from ancient ivory [1] has not been found satisfactory in Egyptian practice.

Bone Bones and bone objects may generally be cleaned by washing with soap and warm water. If salt is present this may be removed by soaking in repeated changes of water until it is all dissolved out, which may be ascertained by testing. If the bone is cracked or not in good condition, it should be wrapped tightly in fine gauze or bound round with fine string or thread before soaking, or if it is in too fragile a condition even for this, it should be strengthened by repeated treatment with a dilute solution (1 per cent.) of celluloid and then soaked. The celluloid, although it will slow down considerably the removal of the salt, will not prevent it. After soaking, the object should be allowed to dry slowly without artificial heat and when quite dry it should be treated repeatedly with dilute celluloid solution, whether this has been done before soaking or not.

Another way of strengthening bones is by means of melted paraffin wax, which, however, darkens them and which for museum purposes the author

[1] W. M. Flinders Petrie, *Methods and Aims in Archæology*, p. 92.

has not found so satisfactory as celluloid, though in the field, paraffin wax is often the best way of strengthening bones in order to permit of their being packed and transported in safety. For the human remains found at Kish the method used [1] "was to pour melted wax over the bones until they were fully encased in a damp-proof solid envelope. In some cases the wax was applied too hot, and penetrated so deeply into the bones that it could only be removed with difficulty, thereby rendering the task of reconstruction extremely hard. For further guidance it should be noted that in our opinion, if wax is to be used, paraffin wax with a low melting-point is the most practicable; and it should be applied at such a temperature that it congeals almost immediately. Sufficient wax should be poured over the object to envelop it entirely. If it is not possible to melt wax in the field, a preparation of turpentine and beeswax, roughly in proportion turpentine 1 litre, beeswax 25 grammes, paraffin wax 10 grammes (preferably with a melting-point of about 125° F.), which can be easily prepared, forms a good hardener and may be recommended to those archæological expeditions who wish to

[1] L. H. Dudley Buxton and D. Talbot Rice, Report on the Human Remains Found at Kish, *Journal, Royal Anthropological Institute*, LXI (1931), pp. 58–9.

preserve bones but have no trained anthropologist with the necessary experience."

In the case of the skull of "Peking Man" which was found embedded, partly in loose sand and partly in very hard travertine (calcareous tufa), whence it was extracted in two blocks, these were first wrapped in layers of soft paper and then in bandages of coarse cloth impregnated with stiff paste.[1]

The practice sometimes employed of coating skeletons or other bones for exhibition purposes with ordinary painter's varnish should never be followed. In the first place it is very disfiguring and in the second place it is quite unnecessary, as several varnishes that are colourless or almost colourless exist and may be used, of which celluloid is the best.

For repairing small bone objects, celluloid cement is recommended; and for large objects, glue or plaster of Paris.

Horn As a rule horn requires little or no treatment beyond cleaning, which may generally be done with warm water. Horn, however, is subject to the attacks of insects, and even ivory and bone are not exempt, though less liable than horn to be attacked. The best remedy if the object is

[1] W. C. Pei, *Bull. Geol. Soc. Peiping*, VIII (1930), pp. 203–5, through *The Museums Journal*, 30 (1930), p. 66.

already attacked, is fumigation as already described.[1] Horn, if broken, may be repaired with celluloid cement or glue.

Jewellery

Ancient jewellery is generally of gold or silver or less frequently of electrum, or of these metals inlaid with stones, faience or coloured glass, or is ornamented with enamel.

Gold, silver or electrum articles, when not inlaid or enamelled, should be treated as described later when the metals are dealt with.

Inlay

Inlay consists of precious or semi-precious stones, faience or coloured glass cut to the required shape and size and fastened in position with a cementing material, and one of the guiding principles in the cleaning of inlaid jewellery is to ascertain, if possible, the nature of the cementing material holding the inlay in place and, either not to use any reagent that would soften or dissolve it, or to employ such reagent with care. For example, if the cement consists of, or contains, resin, as is often the case, alcohol if necessary for cleaning should be used sparingly; if the cement contains whiting or glue, prolonged soaking in water should be avoided.

Acids and alkalies should never be used, for

[1] See p. 50.

not only may the cement be dissolved, but some of the materials forming the inlay may be attacked, thus lapis lazuli, malachite and calcite are all acted upon by acids, and turquoise is affected by alkalies.

Enamel Enamel differs from inlay in that it is a vitreous material applied in the state of powder and fused by heat on to the metal base.

Cleaning The method of cleaning inlay and enamel naturally depends upon the nature of the dirt or incrustation upon it. Ordinarily, warm water applied by means of a soft cloth or cotton-wool will be found sufficient, but, if not, soap and water should be tried. If water, or soap and water, are without effect, an organic solvent is usually indicated and petroleum spirit (benzine, petrol) should first be tested, and then alcohol. In some cases, as for instance occasionally with pieces of the jewellery from the tomb of Tut-ankhamūn, it was found that the object required soaking in the water or other solvent and well brushing from time to time. With such treatment, pieces of the inlay are almost sure to fall out and their position must be carefully noted so that, after cleaning, they may be replaced.

In exceptional cases, special solvents will be necessary, thus to clean the miniature inlaid gold coffins from the canopic box of Tut-ankhamūn,

which were covered with a thick layer of black material looking like pitch (though it was not pitch, but a mixture of resin and fatty matter, with possibly some wood pitch, but no mineral tar or mineral pitch), it was found that both pyridine and acetone gave satisfactory results and the latter was used. Incidentally it may be mentioned that, after the acetone treatment, the gold was cleaned with ammonia. The results were very satisfactory, and the only inlay that came out were a few small pieces that were partly detached previously.

For enamel that has cracked and is separating from the metal base, Scott recommends [1] treatment with a solution of Canada balsam in benzol, after partial exhaustion of the air, so that the balsam may penetrate freely. This treatment has been adversely criticized [2] on the grounds that the balsam will darken and will eventually crack and break up. Hot melted paraffin wax or a solution of celluloid would be good substitutes for the balsam. To repair jewellery, when the inlay has come loose or fallen out, celluloid cement is recommended.

[1] Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, First Report, 1921, pp. 6–7.

[2] W. F. Feid, *Journal, Royal Society of Arts*, LXX (1922), p. 336.

Leather

Leather is very subject to deterioration: it readily dries and becomes brittle and when exposed for long periods of time to moist heat in a closed tomb, as was the case with the leather objects from the tomb of Tut-ankhamūn, it becomes viscous and "runs" and afterwards dries again and when found it may be black, brittle and lustrous and very like pitch in appearance. At other times it is of a brown colour and resembles resin very much in appearance for which it may be mistaken. In either of these states it is softened by, and largely soluble in, water (as much as 85 per cent. being soluble in one specimen tested) and it may be removed from objects to which it is adhering by means of hot water. It is, however, beyond treatment.

Sunlight is very injurious to leather, from which, therefore, it should be protected, but the most common cause for the present-day deterioration of leather is exposure to the sulphur acids that are formed by the combustion of coal and coal gas, certain vegetable-tanned leathers being especially susceptible.

Leather even in a good state of preservation becomes dirty and requires cleaning, which may be done by means of soap and water, a lather of good quality soap, as nearly neutral as possible,

being put on with a soft brush, such as a badger-hair shaving brush, and afterwards completely removed with a damp sponge or cloth. After washing and while still slightly damp,[1] the leather should be brushed over with an oily rag, the oil used being preferably castor oil, which keeps the leather in good condition and restores to some extent the suppleness it may have lost, but which is only of use if the deterioration has not proceeded too far. Any oil that readily becomes acid, such as most animal and vegetable oils, particularly neatsfoot oil and olive oil, which are sometimes recommended, should be avoided, but castor oil, lanoline, sperm oil, and vaseline may all be employed. The oil or grease chosen should be used warm and should be smeared on the leather with a soft cloth or with the hand and well rubbed in, if the condition of the leather will allow, the treatment being repeated from time to time. When leather is too brittle to bear much handling, the object may be treated with a mixture of alcohol (75 per cent.) and castor oil (25 per cent.), which may be applied with a soft brush, or in which the leather may be soaked.

[1] This may appear contrary to what might be expected, oil not usually being applied to damp objects, but experience shows it to be sound, a possible explanation being that the water swells and separates the fibres and so allows the oil to penetrate better.

The author has found a solution of lanoline in petroleum spirit (benzine, petrol), which may be sprayed on, sometimes gives good results.

Oil or grease, however, even though colourless or almost colourless, if applied in such quantity or in such a manner as to be absorbed by the leather, darkens it, and if the leather is dyed, particularly if light-coloured, the appearance may be spoiled.

For the preservation of leather book bindings there are numberless recipes, two of the best of which may be mentioned. Mr. F. W. Clifford, Librarian of the Chemical Society, suggests [1] a preparation of melted paraffin wax to which sufficient lanoline has been added to produce on cooling a grease melting at the temperature of the hand. This should preferably be applied with the fingers, as a cloth may pick up grit that would scratch the leather. Dr. H. J. Plenderleith, of the British Museum Research Laboratory, recommends [2] a mixture prepared by dissolving beeswax ($\frac{1}{2}$ ounce) in hexane, a colourless inflammable liquid derived from petroleum, (11 ounces), in a warm place,[3] then adding cedar wood oil (1 fluid

[1] F. W. Clifford, The Care and Custody of Books, *Journal, Society of Chemical Industry*, 45 (1926), p. 795.

[2] H. J. Plenderleith, The Preservation of Book Bindings, *The British Museum Quarterly*, II (1927), pp. 77–8.

[3] With due precautions against fire risks.

ounce) and finally anhydrous lanoline softened by warming. After washing the bindings and drying them slowly for several days in a warm room, the dressing is well rubbed in with the hand and left for 48 hours, after which the leather is well polished.

All leather is injured by heat, wet leather being particularly susceptible, much more so than dry leather, and Procter states[1] that "The utmost temperature that wet leather will stand is about 120° F., or as hot as the hand will bear . . ." and also[1] that ". . . a pair of wet shoe soles rested on a railway hot water tin for half an hour will be absolutely burnt, so that when dry they will break like glass. . . ."

Leather is subject to the attacks of various insects, particularly cockroaches, and, in Egypt, silverfish insects and "woolly bears," the latter being the larvæ of a small beetle (*Anthrenus vorax*), which may easily be kept at bay by well-fitting show cases and by the frequent moving and dusting of the objects, and if these become infected, the insects may be killed by fumigation with carbon disulphide or a mixture of ethylene dichloride and carbon tetrachloride.[2]

In this connexion it may be useful to refer to

[1] H. R. Procter, *The Making of Leather*, 1914, p. 142.
[2] See p. 50.

a method adopted by Scott for unrolling a very brittle inscribed leather roll in the British Museum.[1] The leather was treated with several coats of a 2 per cent. solution of celluloid in equal volumes of acetone and amyl acetate by means of a soft brush, and as it was unrolled it was fastened to butter muslin that had been treated with a 6 per cent. solution of celluloid; finally it was pressed between two glass plates and dried.

Metals

The metals that will be dealt with are copper and its alloy bronze; gold and its alloy electrum; iron, lead, silver and tin.

Copper and Bronze

The most important metal used in antiquity was copper, which at first was employed alone and afterwards in the form of bronze. This copper is never pure, but contains small proportions of other ingredients, the most common of which are antimony, arsenic, bismuth, iron, tin, and sulphur. The total impurities generally amount to about two or three per cent., though occasionally they are more.

Bronze is essentially an alloy of copper and tin, with sometimes a little zinc. The proportion of the two metals in modern bronze is usually about

[1] Dr. Alexander Scott, *The Journal of Egyptian Archæology*, XIII (1927), pp. 238–9.

90 per cent. of copper to about 10 per cent. of tin. In ancient bronze the proportion of tin is not so constant as in the modern article, and varies from about 2 per cent. to about 16 per cent., but frequently it is much the same as in modern bronze, namely, about 10 per cent. The impurities in ancient copper are naturally found also in ancient bronze, with sometimes the addition of lead, which may be present in proportions ranging from a trace to about 25 per cent. The advantage of bronze over copper is twofold: first, it is harder than copper, and second, the melting-point is lower, thus enabling castings to be made more easily.

Copper and bronze objects corrode very readily, the agents responsible being present either in the air, if the objects are exposed; or in the ground, if the objects are buried. The principal of these agents are carbon dioxide; water-soluble carbonates; chlorides (chiefly common salt); and sulphur compounds (sulphuretted hydrogen and sulphur acids).

After long exposure to a polluted atmosphere, such as that of manufacturing towns or large cities, copper becomes covered with a green patina that consists essentially of basic copper sulphate with a small proportion of basic carbonate and sometimes also a small amount of

basic chloride and occasionally a little sulphide.[1] Near the sea, if the atmospheric pollution is low, the patina always contains a large proportion of basic chloride and may even consist principally of this compound.[1]

Under Egyptian conditions of burial, which differ considerably, but which are often either in a calcareous, salty sand, subject to moisture from occasional rain or from infiltration water, or in damp earth, copper and bronze objects generally become coated with a thick crust of the products of corrosion, which is ordinarily and principally of a green colour, but which in part may be blue, red or black. The green consists of basic copper carbonate (malachite), with often an admixture of basic chloride; the blue is another form of basic carbonate (azurite); the red is copper oxide; and the black is usually another copper oxide or it may be copper sulphide, or both. In the case of bronze, compounds of tin are also formed, as well as compounds of lead, if this latter metal is present in the alloy.

Naturally with such a diversity of compounds to deal with, the methods of cleaning differ considerably.

[1] W. H. J. Vernon and L. Whitby, The Open-Air Corrosion of Copper, *Journal, Institute of Metals*, XLII (1929), pp. 181–202; XLIV (1930), pp. 389–96.

Preliminary Treatment

A preliminary treatment is common to all methods of cleaning and consists in removing loosely adherent matter, which may be done by soaking in water and brushing with a stiff bristle brush. In no case should any incrustation be removed with a knife or chisel,[1] though this is often done and the object in consequence is badly scratched.

Tarnish

A simple tarnish, which usually consists of a thin film of copper sulphide, should be allowed to remain.

Slight Corrosion

Slight corrosion, when it consists, as it often does, of a pleasing thin, hard, smooth patina of a green or blue colour with sometimes a little red or black and of uniform thickness, which shows no signs of active decomposition, should be allowed to remain, though if the patina is not of uniform thickness but is lumpy and ugly and is hiding some of the details of the shape or design of the object, or is manifestly becoming worse, it should be removed, which may be done as follows.

If the object has been coated with oil, wax or varnish, as is often the case especially with objects obtained from dealers, it should first be boiled for about 15 minutes in a dilute solution of caustic soda (10 parts of caustic soda by weight to 100 parts of water by volume) in order to remove

[1] Respecting the use of a chisel, see pp. 96–7.

the coating. After this preliminary treatment, which is only necessary when oil, wax or varnish has to be taken off, the object should be rinsed in water and well brushed with a stiff bristle brush. It is then further treated by means of an alkaline solution of Rochelle salt [1] (sodium potassium tartrate), which is made by dissolving 15 parts by weight of Rochelle salt and 5 parts by weight of caustic soda in 100 parts by volume of water. The object is immersed in the solution for some hours or overnight, after which it is taken out, well brushed with a stiff bristle brush, such as a nail-brush or tooth-brush, rinsed in water and, if not clean, returned to the solution and the treatment, with occasional brushing, repeated until all the corrosion is removed. Sometimes the use of a tiny chisel of the kind to be described later [2] will be found helpful for removing the last traces

[1] This was first recommended by Dr. Alexander Scott (*The Cleaning and Restoration of Museum Exhibits*, First Report, p. 12; Second Report, p. 7), though boiling in cream of tartar (potassium bitartrate) was employed as early as 1808 (J. de Bast, *Recueil d'antiquités . . . trouvées dans la Flandre*, 1808, p. 99); recently a mixture of tartaric acid (1 part), caustic soda (1 part), and water (10 parts) has been proposed and is stated to be as effective as alkaline Rochelle salt, quicker in its action and cheaper (Sana Ullah, *Annual Report of the Archæological Survey of India*, 1924–25 (1927), p. 141).

[2] See p. 96.

of the softened and loosened corrosion from hollows or corners.

After the object is clean, it should be well washed by first soaking it in repeated changes of water for several hours and finally leaving it in water overnight, as thorough washing is essential. If the Rochelle salt is not effective, though usually it is satisfactory for slight corrosion, acetic acid (20 parts of strong acid [1] to 80 parts of water) and Rochelle salt should be used alternately, the object being taken out of the solutions from time to time, rinsed in water and well brushed and when clean finished off with Rochelle salt, a final treatment with this reagent being essential to success. The object is well washed.

Occasionally an object, otherwise in good condition, and having a pleasing patina, shows spots of green corrosion. This is the so-called "bronze disease" and is largely due to the presence of copper oxychloride, and unless cured it will increase. In most cases the trouble may be removed without destroying the patina by prolonged soaking in sodium sesquicarbonate solution [2] (20 parts by weight of sesquicarbonate to 100 parts by volume

[1] Ordinary strong acid, not the glacial acid.

[2] This was first recommended by Dr. Alexander Scott (*The Cleaning and Restoration of Museum Exhibits*, Third Report, p. 36).

of water) until the solution ceases to show any evidence of chloride when tested, when the object is well washed and dried.

Considerable Corrosion

In cases of considerable corrosion there can be no doubt that the whole of the patina and corrosion must be removed, and as a rule neither Rochelle salt nor acetic acid will be sufficient for this, the great difficulty consisting in the removal of the coating of red oxide of copper that generally underlies the green corrosion and only becomes visible when this has disappeared, and that is very ugly and often conceals further corrosion. The most satisfactory method of removing this red oxide, in the author's opinion, after repeated trials, is by means of a cold dilute solution of sulphuric acid[1] (5 or 10 parts of strong acid to 95 or 90 parts of water). The use of mineral acids (sulphuric, hydrochloric and nitric), which are frequently lumped together for censure without discrimination, although their properties and action differ considerably, is often condemned by those who are not chemists as "drastic"[2] and productive of "pitting,"[2] and it is even stated that acid

[1] Acetic acid dissolves red oxide, though not so well as sulphuric acid; Rochelle salt and caustic soda also both dissolve red oxide (J. W. Mellor, *Inorganic and Theoretical Chemistry*, III, 1923, p. 124), but under the usual conditions of working the action is very slow.

[2] See p. 103.

dissolves "some of the metal core"[1] and that it destroys "the details."[1] All this is certainly true of nitric acid, which acts quickly and energetically upon both copper and bronze (but which some of those who object to mineral acids as part of any chemical treatment, use and recommend for the removal of the reduced copper left on an object after the electrical treatment[1]), but it is not true either of sulphuric acid or of hydrochloric acid if these are used in dilute solution. Dilute sulphuric acid of the strength recommended and employed in the manner described has, at the most, a negligible action on copper and bronze[2] and it is only if employed strong or hot that any considerable action takes place. The pitting seen after cleaning a much-corroded object, has not been caused by the reagent used (unless this is nitric acid), but by the process of corrosion, which leaves the metal pitted and spongy, a condition that only becomes visible after the products of the corrosion have been removed. The use of hydrochloric acid is better avoided, except in

[1] See p. 103.

[2] Special tests were made by immersing clean bright copper in 10 per cent. sulphuric acid, and not until the fourth day could any copper be detected in the acid and then only a trace, and not until the ninth day was there sufficient copper dissolved to impart a very slight green colour to the solution.

special cases,[1] for reasons that will be given later.[1]

In Egypt, and doubtless elsewhere, there is a further reason for using sulphuric acid than the removal of red oxide, namely that copper and bronze objects are often brought to the museum directly from the excavations without having undergone any preliminary cleaning, and these objects are frequently encrusted with, or stuck together by, a hard deposit, usually consisting of calcium carbonate (carbonate of lime) or of sand cemented with calcium carbonate, which can only be removed by means of acid, and, as sulphuric acid is the best agent to employ, its use thus becomes necessary. In all such cases the object is immersed in a 10 per cent. solution of sulphuric acid (10 parts of strong acid to 90 parts of water), left for about an hour, taken out, rinsed with water and well brushed with a stiff bristle brush; or the softened and loosened corrosion is removed with a small chisel of the kind that will be described later.[2] It is then returned to the acid and the soaking, brushing and chiselling continued until it is fairly clean. It is then transferred to alkaline Rochelle salt solution and left for several hours with periodical inspection, brushing and chiselling. If still not clean, the alternate treat-

[1] See pp. 93–4. [2] See p. 96.

ment with sulphuric acid and Rochelle salt is continued until all the corrosion has been removed. The final treatment must be with Rochelle salt, after which the object is thoroughly washed as described.[1]

Occasionally, instead of the encrusting or cementing material being calcium carbonate, it consists of calcium sulphate (sulphate of lime), which is only very slightly soluble in sulphuric acid and must be removed by heating the object with dilute hydrochloric acid (20 parts of strong acid to 80 parts of water). After the use of hydrochloric acid, the object should be well washed and treated with Rochelle salt and then alternately with sulphuric acid and Rochelle salt as already described until it is clean. With this exception, the use of hydrochloric acid should be avoided, as it is very difficult to eliminate and, although it is without appreciable action on copper or bronze during the short time it is ordinarily used, this is not the case when left to act for an indefinite period, as happens if it is not entirely removed; it also forms common salt with the caustic soda in the alkaline Rochelle salt used for finishing off, and this, which is a very active agent of corrosion, is most difficult to remove from the spongy metal by washing.

[1] See p. 107.

Also, no matter how thoroughly an object has been cleaned, traces of corrosion are liable to be left in the metal (which is usually very porous) or in corners or inside hollow objects on which the hydrochloric acid would act, forming copper chloride, which might be the starting point for corrosion of the worst kind.

Although there may not be any calcium carbonate to necessitate the use of sulphuric acid, this does not debar its use and the object may first be treated either with Rochelle salt or with sulphuric acid and then alternately with the two reagents with the usual brushing or chiselling [1] until clean, when it should be finished off with Rochelle salt and thorough washing. As the cleaning progresses, the length of time it is necessary to leave the object in the acid will decrease until a few minutes' immersion will be sufficient.

Even with slight corrosion the object may be treated with sulphuric acid and Rochelle salt alternately, instead of with acetic acid and Rochelle salt, but in this case only a very short immersion in the acid will be required.

The length of time it is necessary to leave the object in the sulphuric acid may vary from a few minutes to several hours, but is usually very

[1] See pp. 96–7.

short. If the cleaning has to be interrupted for any reason, for instance at night, the object should not be left in the acid, but should be rinsed and transferred to an alkaline solution of Rochelle salt, after which, when the cleaning is resumed, it should be rinsed, brushed and replaced in the acid.

The use of sulphuric acid is not advisable for copper or bronze objects that are inlaid with gold, as is sometimes the case, as the acid would remove any red oxide or other corrosion there might be beneath the gold, which consequently would come off. Such objects should be treated with sodium sesquicarbonate, or with Rochelle salt.

The orange-yellow deposit often seen on an object undergoing the Rochelle salt treatment is merely a modification of the red oxide of copper and is readily brushed off. Its presence is a most useful indication that the red oxide has not all been removed and that a very short further treatment with acid is needed.

When an object that is coated with red oxide of copper is immersed in sulphuric acid, the oxide is decomposed, or "reduced" as it is termed, the original copper being regenerated. This reduced copper, however, is not metallic-looking, but has almost the same colour and appearance as the red oxide and, as it is in the condition of slime,

it usually brushes off readily. Occasionally, however, if too hard a brush is employed, such for instance as a brass wire brush, some of the reduced copper is burnished on to the surface of the object, forming a bright metallic coating that has all the appearance of being the original metal cleaned and polished. The formation of such a coating should be carefully avoided, partly because a bright surface is not generally desirable, but more especially because under the layer of bright reduced copper there is almost always corroded material, which, although hidden and bottled up for the time being, eventually manifests itself, with the result that the object becomes in almost as bad a condition as it was originally. If, in spite of all precautions, the reduced copper, instead of being brushed off, becomes adherent (which usually takes place in patches) it must be removed, which can be done by the use of a tiny chisel, the operation being easy to carry out and without any danger to the object.

The chisels used by the author are small round steel ones from 10 to 15 centimetres (4 to 6 inches approximately) long and from 4 to 5 millimetres (0·16 to 0·20 inch approximately) in diameter, with the usual chisel-shaped edge, of which some are 1 millimetre and some 2 millimetres across (0·04 to 0·08 inch approximately). With these

chisels, a tiny hammer of the kind used by jewellers is often found helpful.[1]

The mechanical method, as already mentioned, is a most useful auxiliary to any of the chemical modes of treatment described and, if reasonable care be taken, the object is not scratched or disfigured in any way. As a rule, the chisels should be used when the object is taken out of the bath to be brushed and (with one exception) they should only be used when the object is wet and when the corrosion has been softened and loosened by chemical treatment. The exception is that of certain kinds of copper objects, generally mirrors, which are often coated with a layer of red oxide that is particularly amenable to flaking and that may be removed dry by means of a small chisel or small hammer, not only without damage, but in such a manner that much of the original polish on the surface remains intact. Mechanical treatment, however, is not suitable for, and should never be applied to, objects that are thin or that are in a fragile condition.

Reverting to sulphuric acid, it should be stated that although not dangerous to copper or bronze,

[1] Dr. E. S. Riggs, of the Field Columbian Museum, Chicago, employs a tiny pneumatic hammer for cleaning fossils that would probably be equally useful for copper and bronze objects (*The Museums Journal,* III (1903–4), p. 208).

it may be dangerous to the operator unless used carefully. Strong sulphuric acid is very corrosive and while being diluted with water considerable heat is generated and unless care is used the acid is liable to splash on to the hands, face or clothes. In order to make the dilute solution, 5 or 10 parts of the strong acid, as the case may be, are poured gradually and carefully into 95 or 90 parts of water with constant slow stirring with a glass rod or piece of wood, care being taken to avoid splashing. On no account should the water be poured into the strong acid. Objects may be put into and taken out of the dilute acid solution with the bare hands without danger, if these are washed immediately afterwards. Care should be taken to avoid splashing the clothes.

A useful substitute for sulphuric acid and one that may be employed without danger, either to the object or to the operator, is potassium hydrogen sulphate [1] (potassium bisulphate, acid potassium sulphate) which is a white crystalline solid soluble in water. It is used in the form of a 10 to 20 per cent. solution (10 to 20 parts of sulphate by weight to 100 parts by volume of water). This is slower in its action than sulphuric acid and the object, therefore, should be left in the solution longer. After the use of the sulphate, a final

[1] Not the normal potassium sulphate.

treatment with alkaline Rochelle salt should be given, followed by the usual thorough washing.

Before leaving the chemical methods of cleaning, it may be noted that, whenever possible, hollow objects and hollow bases and stands of objects should be emptied and cleaned, even though the filling may not be adventitious, but the black sand or other material used originally as a core for casting, since anything of this nature not only prevents thorough cleaning, but acts as a sponge and soaks up and retains the chemical reagents employed. It may also contain salt and thus act as a focus for further corrosion.

Electro-chemical Methods

Electro-chemical methods are those in which a feeble electric current is generated by the action of a metal (such as zinc, aluminium or tin) in contact with the object to be cleaned, both being immersed in an alkali or acid. There are many variants, the simplest and best of which is to employ zinc and caustic soda. The details of the process are as follows. Take an enamelled iron or other vessel and in this place a layer of granulated zinc. On the zinc lay the object to be treated and on this more zinc until the object is completely covered. Add a dilute solution of caustic soda (5 to 10 per cent.), heat and allow to simmer gently for several hours. If thin pliable strips of zinc are obtainable, it is often preferable

to wrap the zinc round the object. When the object is removed it will be found coated with a black deposit. It is rinsed in water and well brushed, while wet, with a stiff bristle brush. If the cleaning is incomplete and there is still corrosion left, the object is replaced in the solution and the heating continued for a further period. Finally, the object is thoroughly washed and well dried. The results of this treatment, although appearing satisfactory at the time, are often disappointing and spots of green corrosion are liable to appear later. Should this happen, the treatment is repeated, or the object is cleaned with Rochelle salt.

A variation of the method just described that may be mentioned is one devised by Krefting [1] for cleaning coins, which the author has generally found satisfactory. The details are as follows. A thin plate of bright zinc is perforated with large holes, 2 to 5 mm. (0·08 to 0·20 inch) in diameter, in such a manner that raised edges are left on one side of the sheet. The holes are so spaced that the coins do not touch one another. The perforated sheet is placed on supports (never flat on the bottom) in a suitable vessel, with the sharp edges of the holes uppermost. The coins to be

[1] F. Rathgen, *Die Konservierung von Altertumsfunden*, II und III (1924), p. 94.

cleaned are arranged over the holes resting on the raised edges and on them are placed other similar sheets with coins one above the other, each with the sharp edges of the holes upwards, except the top sheet (without coins), the raised edges of which should be downwards resting on the last layer of coins. Weights are then put on the sheets to keep them in position. A solution of caustic soda (5 to 10 per cent.) is added in sufficient quantity to cover the sheets and the whole is left for about 18 hours, when the coins are removed, brushed with a stiff bristle brush and thoroughly washed in repeated changes of water. As the coins are usually in different states of corrosion, some of them may not be completely cleaned and, if so, these are re-treated, or, if the corrosion is very obstinate, they may be finished with alkaline Rochelle salt or with dilute sulphuric acid and afterwards with Rochelle salt.

Electrical Methods

For purely electrical methods of cleaning the current is derived from some kind of primary battery (such as three or four Daniell's cells); from accumulators or from the ordinary electric supply from the mains, though in the latter case, if the current is the usual alternating one it must be converted into a direct current by the use of a rectifier.

The electric method of cleaning corroded museum

objects appears to have been first described by Finkener [1] but it has recently been studied in detail and employed by Professor C. G. Fink and Mr. C. H. Eldridge [2] and also by Mr. H. W. Nichols,[3] who have obtained with it very satisfactory results. The object to be treated is suspended as cathode between iron or platinum anodes in a dilute (2 per cent.) solution of caustic soda, and 110 volts direct current (0·1 to 0·5 amperes) is passed through the system for several days after which the object is taken out of the solution, cleaned and finally well washed. Mr. Nichols points out that [4] "the process has two disadvantages. It requires special equipment and close supervision by a man skilled in handling antique bronzes and by a skilled chemist." As the necessary appliances are frequently not available and as the method to the inexperienced is less simple than either chemical or electro-chemical methods, the usefulness of the purely electrical method is practically limited to large museums. After the electrical part of the treatment, the object must be finished off by mechanical or

[1] F. Rathgen, *op. cit.*, p. 79.

[2] C. G. Fink and C. H. Eldridge, *The Restoration of Ancient Bronzes and other Alloys*, New York, 1925.

[3] H. W. Nichols, *Restoration of Ancient Bronzes and Cure of Malignant Patina*, Chicago, 1930.

[4] H. W. Nichols, *op. cit.*, p. 8.

chemical methods, such as brushing with a stiff bristle brush [1, 2] or with a soft wire brush,[1, 2] by chipping [3] or by dipping in dilute nitric acid [4, 5] (20 parts of strong acid to 80 parts of water), both chipping and acid, however, being adversely criticized when used as part of the chemical method of cleaning.[6]

The author has tried the electrical method of treatment and, although the results were generally satisfactory they were not better than those obtained by either purely chemical methods or by electro-chemical methods, and he is in agreement with Dr. Alexander Scott [7] that "for safety and with the simple appliances at the command of most curators of museums and other collectors, the treatment with zinc in alkaline, or it may be in acid, solutions will be found most generally useful." The author, however, would like to emphasize the value and safety of some of the purely chemical methods when carefully carried out.

[1] C. G. Fink and C. H. Eldridge, *op. cit.*, p. 16.

[2] H. W. Nichols, *op. cit.*, p. 36.

[3] H. W. Nichols, *op. cit.*, pp. 36, 41, 42.

[4] C. G. Fink and C. H. Eldridge, *op. cit.*, pp. 17, 18, 20.

[5] H. W. Nichols, *op. cit.*, p. 43.

[6] C. G. Fink and C. H. Eldridge, *op. cit.*, pp. 7, 8, 10, 12, 14.

[7] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, Third Report, 1926, p. 38.

Preservative Coatings

It is often found that copper and bronze objects submitted for cleaning have been oiled or waxed, the reason being partly to give the metal a duller and darker surface, partly to form a protection against atmospheric influences, especially moisture, and in the case of wax, to fill up the pores of a spongy metal that has been cleaned, to hide defects and to produce a uniform surface with a certain amount of polish. Whether the appearance is improved is a matter of individual taste, but in the author's opinion such treatment is better avoided and, if the object has been thoroughly cleaned, protection from atmospheric moisture is not required.

Patina

It is only necessary to inspect any exhibition of modern sculpture, or the excellent reproductions of antique bronzes made in Italy and Greece, to realize that a new copper or bronze object may be given almost any kind or colour of patina desired. It is otherwise, however, with ancient copper or bronze that has been corroded and cleaned, as the surface being no longer smooth and polished does not take the colour uniformly.

In the author's opinion the deliberate application of artificial green patina to an ancient object is unsound in principle. It does not reproduce the original appearance and naturally it cannot be any evidence of age. The practice is due,

partly to the general knowledge that ancient copper and bronze objects as found are frequently green and hence to the fear that an object that is not green may be looked upon as not genuine, and partly to the idea that a patina enhances the beauty of an object. It is acknowledged that a patina may be more pleasing than a bright polished surface, and that a green patina on a modern bronze is often beautiful, but to obtain such a patina on ancient objects is impossible and the poor substitutes that alone are possible are usually not beautiful. A great disadvantage, too, of the modern green patina is that it is often produced by means of hydrochloric acid or of soluble chlorides and therefore it may be the starting-point of fresh corrosion, chlorides being the agents that cause the so-called "malignant patina" or "bronze disease." The aim in cleaning antique objects should be to restore, as far as possible, the original appearance of the object, which in the case of copper and bronze, is neither the brightness of new metal nor the green of artificial patina, but the slightly dull appearance of metal in everyday use.

Cleaning does not always produce a bright surface on copper or bronze, the result depending upon several factors, including the composition of the alloy, the nature of the cleaning process

employed and the kind of brush used. A bright surface even if produced, does not last long but inevitably becomes dull after a short period of exposure. If it is not desired to wait for a natural tarnish to form, the surface may be dulled and tinted black or brown by simple means. Thus a slight black coloration may be obtained by immersing the object in a very dilute solution of sodium sulphide (about 0·1 per cent.[1]), rinsing it quickly in water and allowing it to dry, or by boiling the object in a dilute solution of sodium thiosulphate (the "hypo" of the photographer). A pleasing slight brown colour may be obtained by immersion in a dilute solution (about 5 per cent.) of potassium permanganate and allowing the object to dry without washing or wiping.

As it is necessary that an object should be entirely free from grease before colouring, otherwise the colour will not be uniform, it is always better to rinse it well in petroleum spirit (benzine, petrol) before the operation.

Objects too Fragile to Clean

When it is impossible to clean an object thoroughly because of its fragility or because no core of solid metal is left, the worst of the corrosion should be removed by one of the preliminary methods described, either that with

[1] The colour is not so agreeable if a strong solution is employed.

sodium sesquicarbonate or that with alkaline Rochelle salt, and after well washing, the object should be treated with dilute sodium sulphide solution in order to hide the very disagreeable colour produced by the partial cleaning, or if the object is very fragile, it should be treated, after preliminary cleaning and drying, with melted paraffin wax or beeswax.

Causes of Failure

In those cases in which a copper or bronze object that has been cleaned shows signs of further corrosion, this is due to one of two causes, either because the cleaning has been imperfect (and it is not always easy to know when the cleaning, especially of a hollow object, is complete), or because the object has not been thoroughly washed. Too much stress cannot be laid upon the necessity for thorough washing, which as a rule means soaking the object for several days in repeated changes of water.

Electrum

Electrum is a light-yellow coloured alloy of gold and silver that was much employed in ancient Egypt. It is described by Pliny [1] as containing 20 per cent. of silver, though actually the proportion of silver varies considerably. According to the author's experience, electrum is rarely, if ever, badly corroded, but usually only disfigured

[1] *Natural History*, XXXIII, 23.

by a thin film of silver chloride or silver sulphide (sometimes visibly crystalline), which may be removed in the manner that will be described when dealing with the tarnish on silver.

Gold When gold is pure it is a bright yellow colour and neither tarnishes nor corrodes, and, therefore, does not require any cleaning beyond the removal of dirt, which may be done by means of soap and warm water, aided by a cloth or soft brush, care being taken to avoid scratching the gold, which is a soft metal and easily marked. If there is any natural red patina, rubbing or brushing should be done with care, otherwise this patina, which is not only pleasing but an evidence of age, may be removed. Occasionally, too, on ancient Egyptian gold there is an artificial rose-pink colour that should on no account be destroyed and that is easily rubbed off.

Gold, however, is rarely pure, but generally contains small proportions of other metals, chiefly silver, copper and iron, which undergo chemical change on the surface and give rise to a discoloration or tarnish, the gold, however, being still comparatively soft and easily scratched.

In order to clean gold when tarnished, it should first be washed with soap and warm water, with gentle rubbing with a cloth or brushing with a

soft brush. If the tarnish still persists, the next step is to apply dilute ammonia solution (10 parts of strong ammonia, specific gravity ·880, to 90 parts of water) with a rag or small sponge, which removes silver chloride, often the chief constituent of the tarnish. In the rare cases in which ammonia is not successful, potassium cyanide [1] should be tried, as this will remove tarnish due to silver sulphide and copper sulphide, which are not soluble in ammonia. This reagent should only be employed in very dilute solution (5 per cent.), as it acts upon and dissolves gold when used too strong, or if left in contact with the gold too long. After treatment, the object must be thoroughly washed in warm water and carefully dried.

Occasionally on the surface of ancient gold there are patches of a dark purplish discoloration apparently due to organic matter, which is not soluble either in ammonia or in potassium cyanide, but which can sometimes be removed by the careful use of plate powder, such as whiting or jeweller's rouge, or sometimes by heating, if the nature of the object will allow of this, which is done by making the object momentarily red hot in the flame of a bunsen lamp or spirit lamp. If, however, the gold is very thin it should not be heated, or it may melt. If, after heating, the gold shows

[1] This reagent is very poisonous.

dark stains (which are generally due to copper oxide formed from copper present in the gold) these can be removed by the action of strong nitric acid, applied either by immersing the object momentarily in the acid or by smearing the acid on by means of a glass rod or a piece of wood. After the acid treatment, the object should be well washed in water, then in dilute ammonia solution and again in water.

Sometimes on ancient gold there are incrustations of calcium carbonate or calcium sulphate. No attempt should be made to scrape these off, as this would scratch and disfigure the gold, but any such deposits may readily be removed by soaking the object in a dilute solution of hydrochloric acid (10 parts of strong acid to 90 parts of water), which is without action on gold. The acid treatment must be followed by thorough washing in water, then in dilute ammonia and again in water.

A number of objects in the Cairo Museum, which were thought to be of solid gold, were much disfigured by an incrustation, that had a metallic appearance, but which on chemical analysis was found to consist of silver chloride in the form of "horn" silver. It was further found that these objects were not of solid gold, but were of silver coated with thin sheet gold, and, in one instance, having silver inlay. The silver had become partly

converted into chloride by the action of salt and it was this chloride that formed the incrustation, and since the conversion of silver into chloride results in a considerable increase of volume, amounting to nearly 33 per cent., this expansion had ruptured the gold casing. As ammonia is one of the best solvents for silver chloride and is without action on gold, the objects were soaked for several days in strong ammonia solution.[1] The silver chloride on the surface was entirely dissolved and that in the interior, being protected by the gold, was not noticeably attacked and the objects were left in excellent condition.[2]

Gilt objects are cleaned in the same manner as those of solid gold or sheet gold, but when the gilt is thin, great care is necessary to avoid damaging the surface and the cleaning should be done with a small sponge or a small soft brush. The gilt surfaces of the shrines that were round the sarcophagus of Tut-ankhamūn, which had a superficial area of about 2,660 square feet, were cleaned by the author with warm dilute ammonia solution applied with a sponge.

As ancient Egyptian gilt is generally on chalk

[1] An inlay of lapis lazuli was removed before treatment and afterwards replaced.

[2] E. Vernier, Bijoux et Orfèvreries, I (1927), pp. 240–1; II (1927), Plates LXIII–LXIV, *Cat. Gén. du Musée du Caire.*

plaster,[1] the precautions that will be mentioned when dealing with this material [2] should be observed. Sometimes on the surface of the gilt there is a characteristic reddish-brown deposit that is confined to the vicinity of cracks and broken edges. Where this has been tested it has been found to consist largely of an exudation of glue from underneath the gilt, on which there is often what appears to be a fungus growth, and it may be removed by frequent applications of warm water applied with a sponge or soft rag.

Iron The fact that iron corrodes readily is a matter of common experience, and rusty iron may be seen almost everywhere. It is very noticeable, too, that on the sea coast iron corrodes more quickly than inland, this being due to the presence of salt.

The principal agents responsible for the ordinary rusting of iron are (*a*) moisture, without which rusting is impossible; (*b*) common salt derived from the ground in which the iron has been buried, from sea air or from salt water; and (*c*) oxygen and carbon dioxide from the air.

In order to clean iron, a simple and satisfactory method, when the condition of the object will allow, is first to remove as much of the rust as possible by brushing with a stiff bristle brush, or

[1] Termed "gesso" by Egyptologists. [2] See p. 185.

a fine soft-iron wire brush, or by flaking with a small chisel or hammer, as used for copper and bronze, and then to place the object, bound round with strips of flexible sheet zinc, or surrounded by granulated zinc, in a solution of caustic soda (5 to 10 per cent.), which is kept gently simmering as already described for copper and bronze. After treatment, the object is rinsed with water and again well brushed, then thoroughly washed, quickly dried and finally immersed in hot melted paraffin wax until impregnated and then removed and allowed to drain. Many iron objects, however, are too thin or too much corroded to bear either mechanical treatment or reduction with zinc and caustic soda, in some instances being only a mass of oxide, and in such cases all that can be done is to boil the object in a solution of caustic soda (10 per cent.) and afterwards in water until all the salt and alkali are washed out. It is then thoroughly and quickly dried by heating and while still hot is immersed in melted paraffin wax. Linseed oil, which is sometimes used instead of wax, is not nearly so efficient and on account of its colour causes disfigurement, whereas paraffin wax is colourless. All oils, fats and greases, except those of mineral origin, should be avoided, as they develop acidity on keeping. Vaseline might be used, but paraffin wax is better.

In the matter of protection from atmospheric influences iron cannot be compared with copper and bronze, since iron corrodes readily when exposed to a damp or polluted atmosphere and therefore needs protection, whereas copper and bronze, if free from salt, merely become covered with a thin patina, often of a pleasing colour, that forms a protection against further corrosion.

Lead Lead oxidizes quickly in moist air, the result, however, being only a superficial tarnish ; natural waters act upon lead and if the water is soft, the lead is corroded, but if the water is hard, a protective film of basic lead carbonate is formed that prevents further action ; fresh lime mortar and Portland cement both corrode lead ; all acids attack lead, the severity of the attack varying with the nature of the acid, thus the mineral acids, hydrochloric acid and sulphuric acids have very little action, while another mineral acid, nitric acid, especially if dilute, dissolves lead readily ; organic acids, even when dilute, also act upon lead, the action of acetic acid being made use of in the manufacture of white lead, and as far back as 1787 it was noticed and recorded [1] that certain

[1] R. Watson, *Chemical Essays*, London, 3, 366, 1787 (J. W. Mellor, *Inorganic and Theoretical Chemistry*, VII, 1927, p. 573).

kinds of wood, particularly oak, in contact with lead act upon it and corrode it by reason of the organic acids they contain, as a consequence of which lead objects should not be kept in direct contact with wood and never in oak cases.

Antique objects of lead in good condition are generally covered with a thin white surface deposit that consists of basic lead carbonate; when lead is badly corroded the deposit may consist either of basic carbonate, or of a mixture of this with lead chloride, the latter being caused by the action of salt.

Although acetic acid has more action on lead than sulphuric acid, and, therefore, is dangerous unless the object is washed absolutely free from all traces of acid afterwards, it has been found in practice to be much more satisfactory for removing corrosion than sulphuric acid, which is generally recommended. If the corrosion is relatively slight, the object is painted over repeatedly with dilute acetic acid (10 parts of strong acid to 90 parts of water) by means of a brush, but if the corrosion is considerable it may be necessary to soak the object in the acid, taking it out and brushing off the corrosion at intervals. After cleaning, the object must be well washed and then soaked for a short time in dilute ammonia solution (5 parts of strong ammonia to 90 parts of water) or in

dilute caustic soda solution (1 part by weight caustic soda to 100 parts by volume of water) and again thoroughly and repeatedly washed with water until on testing with litmus paper no trace either of alkali or acid can be found. When using ammonia or caustic soda it must not be forgotten that both these reagents act upon lead, therefore the treatment must not be too prolonged.

In one instance in the author's experience, thin sheet lead bearing an incised inscription in Greek, although in good condition so far as the metal was concerned, was badly disfigured by adherent material, that was found to consist of a mixture of earthy matter and resin. This was taken off by alternate washing with warm water (to remove the earthy matter) and acetone (to remove the resin), applied with a soft brush.

As lead chloride is easily soluble in water, this compound is removed automatically during any washing process, but to make sure that no chloride is left, the wash water should be tested in the usual manner and, if chloride is found, the washing should be continued with warm water until no further reaction is obtained.

To consolidate lead objects and to protect them from further disintegration, they should be treated, either after cleaning (or without cleaning, if their condition is too fragile to allow of cleaning) with

dammar, shellac or mastic varnish, in such a manner that no gloss is left on the surface, which may be done by using the minimum amount of a dilute solution.[1] Celluloid solution is not recommended for use on lead, as there might be some slight formation of nitric acid on keeping, due to the decomposition of the celluloid, that would attack the lead.

Jenkinson,[2] after cleaning leaden seals with dilute hydrochloric acid (0·8 per cent.[3] strength), treating them with very dilute ammonia to neutralize the acid, well washing with water and drying by means of alcohol, coated them on the advice of the Government Chemist with methyl cellulose in place of celluloid.

When cleaning lead objects it should not be forgotten how very soft and easily marked or scratched this metal is.

Silver

Silver as employed for making jewellery, ornaments, plate and other objects is never pure, but always contains other metals, notably copper.

Ancient silver, and particularly old Egyptian

[1] See p. 54.

[2] Hilary Jenkinson, Some Notes on the Preservation, Moulding and Casting of Seals, *The Antiquaries Journal*, IV (1924), p. 396.

[3] This is given as 8 per cent., which is believed to be a printer's error for 0·8 per cent.

silver, varies very much in its state of preservation, the severity of any corrosion ranging from a slight surface discoloration or tarnish to a condition so bad that the metal has wholly disappeared and has been replaced by the compounds resulting from the chemical changes that have taken place. Naturally these different conditions require different methods of treatment. As it is impossible to describe separately each of the infinite stages or degrees of corrosion, these will be divided for the sake of convenience into three main groups, namely, (*a*) tarnish, (*b*) slight corrosion, and (*c*) considerable corrosion, which may now be considered.

Tarnish This is a very thin grey or black film on the surface of an object, which otherwise is in excellent condition and perfectly sound. On ancient silver the film ordinarily consists of silver chloride, but occasionally may be silver sulphide (sometimes visibly crystalline), with possibly a little copper sulphide derived from copper alloyed with the silver. On modern silver, or on ancient silver that has acquired a recent tarnish, the film is usually sulphide.

As even a slight tarnish on silver, unlike that on copper or bronze, is disfiguring and hides the beauty of the object, it should generally be removed. This may often be done, if the object is of such a nature that it can be brushed without injury, by means of soap, warm water and a soft

brush, followed by drying with a soft warm cloth or chamois leather. Whiting, made into a cream with soap and water, will often be found helpful. This is prepared by dissolving good quality white soap in just sufficient hot water to make a jelly when cold and stirring in whiting in fine powder until the whole has the consistency of cream. The mixture is applied cold with a soft cloth, then rinsed off with warm water and the object dried with a warm cloth.

A slight tarnish may also readily be removed by chemical means, silver chloride being soluble in a solution of ammonia and also in a solution of potassium cyanide, which latter also dissolves both silver sulphide and copper sulphide. Since the tarnish on ancient silver is usually due to chloride and rarely to sulphide, ammonia will generally remove it, and as ammonia is more easily procurable and less dangerous than potassium cyanide (which is very poisonous), ammonia is to be preferred, the strength of the solution employed being about 10 parts of strong ammonia (specific gravity ·880) mixed with 90 parts of water. After cleaning, the object should be well washed and dried. A disadvantage of ammonia is that when it has been used to dissolve silver chloride, it stains the hands and particularly the nails, the stains being most difficult to remove,

those on the nails usually remaining until they can be cut off as the nail grows, which takes several months. Also if the ammonia is strong it causes blisters. In order to prevent either staining or blisters, therefore, indiarubber gloves should be worn.

Ammonia is almost without action on silver, and although it acts upon any copper present, this action under the conditions in which it is used is negligible. In the rare cases in which the tarnish is due to sulphide, potassium cyanide (5 per cent. solution) must be used. This acts slightly upon silver, but if employed in dilute solution and if the object is well washed afterwards, this action may be disregarded. The ammonia or cyanide may be applied by means of a tuft of cotton-wool, a piece of rag or a soft brush. After cleaning, the object must be thoroughly washed and carefully dried.

Another method of removing tarnish from silver is to place the object in contact with aluminium in a solution of sodium carbonate, which may be done by making a solution of ordinary washing soda (about 20 or 25 per cent. strength) in an aluminium saucepan or dish and immersing the object in the solution for about 5 or 10 minutes, when it should be taken out, washed well with warm water and dried with a soft warm cloth. Since aluminium is vigorously acted upon by soda,

if the action is allowed to continue too long, or if the operation is often repeated with the same vessel, this will soon be destroyed. Instead, however, of an aluminium vessel, a large piece of aluminium may be placed in contact with the silver object in a porcelain basin filled with sodium carbonate solution.

Slight Corrosion

This, though largely consisting of silver chloride, also contains compounds of copper originating in the copper alloyed with the silver. When the silver is of poor quality and contains a large proportion of copper the corrosion may be of a green colour and the object may look so like corroded copper or bronze that it will often be mistaken for these metals, and it is not until it has been cleaned that its true nature will become manifest.[1] As already stated, two excellent solvents for silver chloride are ammonia and potassium cyanide respectively, which have been recommended for removing tarnish. But with any corrosion greater than tarnish, simple rubbing of the surface with a dilute solution of the solvent would be useless, and it becomes necessary to soak the object in the solution and to leave it for several hours at least and possibly for days. Under these conditions the use of potassium cyanide is not advisable, for not

[1] Several such cases have occurred in the author's experience.

only does it attack and dissolve the gold of any gilding that may be, and often is, present on silver objects of certain kinds and periods, but it also dissolves silver to some extent, destroying any polish and producing an unpleasant-looking mat surface, which, however, may be removed and the polish restored by gentle burnishing.

Ammonia solution is almost without action on pure silver and, although the silver of which objects are made is never pure, treatment with ammonia is an invaluable remedy for corrosion, since although the silver is alloyed with copper and although ammonia attacks and dissolves copper, the action is only slight with alloys containing less than about 20 per cent. of copper, which is an unusually high proportion to be present. The ammonia used should be a 20 per cent. solution (20 parts of strong ammonia, specific gravity ·880, to 80 parts of water) and the object should be immersed and left for several hours or overnight. It should then be taken out,[1] brushed carefully with a brush not hard enough to scratch it, and finally well washed in repeated changes of water. If the object is not clean, the treatment should be repeated.

A useful adjunct to ammonia for the removal of slight corrosion, particularly from poor quality

[1] See p. 120 for precautions to be taken to avoid staining or blistering of the fingers.

silver containing a large proportion of copper, is hot formic acid,[1] which is best used alternately with ammonia. The object is placed in a suitable vessel (not of metal or enamelled iron) and a solution of formic acid sufficient to well cover it is added and the vessel heated. The strength of the acid may vary from 5 to 25 per cent., but it is usually better to begin with about 10 per cent. (10 parts of strong acid to 90 parts of water). The object is allowed to remain in the acid for about an hour, then taken out, rinsed in water and well brushed with a brush not hard enough to scratch it, then immersed in ammonia solution (20 parts of strong ammonia to 80 parts of water) and left for some time, after which it is again rinsed in water and brushed. If the object is still not clean, the alternate treatment with formic acid and ammonia is repeated, the strength of both the acid and ammonia being increased if necessary. Finally the object is well washed and dried.

Considerable Corrosion

Corrosion may be so considerable that the object is coated with a thick lumpy crust that hides all detail, not only of ornament, but also of shape, the general outline of the object only being recognizable, and it is sometimes impossible to know

[1] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, First Report, p. 8 ; Second Report, p. 5 ; Third Report, pp. 23–4.

what the object is. Occasionally there may be a core of solid coherent silver under the corrosion, but more often any silver remaining is in a very brittle and rotten condition, and frequently there is little or no silver left. This crust, like that on less corroded objects, consists largely of silver chloride mixed with small proportions of copper compounds derived from the copper contained originally in the silver. Sometimes the silver chloride is in the form of "horn silver," which is very adherent and resembles lead somewhat both in appearance and hardness, and which may be cut with a knife, though no attempt should be made to remove it in this manner, as the result would certainly be failure and probably disaster. When the object has a core of silver left, whether this is solid and coherent or not, it may be treated as already described for slight corrosion, namely, with hot formic acid followed by ammonia, but more prolonged treatment is necessary than in the case of slight corrosion, and the ammonia should be stronger [1] (equal parts of strong ammonia and water). Much of the corroded material will either dissolve or will fall off in the solutions, or may be removed by brushing. After experience of the mechanical treatment of copper and bronze, there

[1] The fumes are strong and disagreeable and should be breathed as little as possible.

will be a great tendency to attempt to flake a silver object in the same manner, but this should not on any account be done, as it is never safe and damage almost always results when force is employed, often, too, just at the end when all seems to be going well. If the chloride, or any portion of it, is persistent and difficult to remove, the only safe method of dealing with it is prolonged treatment with 50 per cent. ammonia (equal parts of strong ammonia, specific gravity ·880, and water) or even with strong ammonia without dilution, though this is expensive and is disagreeable to work with on account of the very strong fumes. After cleaning, the object should finally be well washed in water and thoroughly dried. If the silver under the corroded surface is in a coherent and solid state, the results of the treatment will generally be satisfactory and, even if the silver core is brittle and rotten, a satisfactory result may usually be obtained if care is taken in handling the object during treatment and particularly if no force is employed in removing the adherent chloride. Unless, however, great care is exercised the object will certainly break, as the silver never has much strength or cohesion.

If an object, of which the walls were originally thin, is much corroded, it is certain that little or no metallic silver is left, and in such a case it is

almost inevitable that during treatment the object will break or may even fall to pieces. This possibility, therefore, must be faced, and a decision made whether it is better to leave the object untouched and corroded, with sometimes its very nature unknown, or to risk damage and even total loss, in the hope that something of interest, or beauty, or even of archæological value, such as an inscription, may be saved. If it is decided to risk treatment, every care possible must be taken in handling the object, especially in the later stages. With objects in this tender condition no attempt should be made to remove the corrosion except with a soft brush.

Hollow objects such as boxes, vases and bowls that are very thin and tender may be strengthened by being lined with a thin coating [1] of paraffin wax, which should be on the point of solidification when used. If there are holes in the object, through which the wax would run out, these should be stopped up from the outside with a thick coating of wax applied with the fingers, the wax being in the plastic condition that is found on the surface of a mass that is cooling. After the lining is finished, the surplus wax on the outside may readily be removed with a small knife, the blade of which has been heated in a

[1] Too thick a coating makes the object too heavy.

bunsen lamp or spirit lamp. One great advantage of lining an object with wax is the ease with which repairs may be executed. All that is necessary, if the loose piece is small, is to place it on the wax and touch it with the heated blade of a penknife, when it sinks into position. If large, the loose piece is inserted before the lining is done and is held in position by plastering over the join from the outside with plastic wax; the lining is then applied and the excess wax on the outside removed with the heated blade of a knife.

In most cases of fragile, hollow objects that are to be lined with wax, this is better done before cleaning and hence any formic acid employed subsequently must be cold. The lining of an object with wax before treatment naturally covers up the corrosion inside in such a manner that it cannot be removed by the cleaning solution, but this corrosion will largely consist of silver chloride, which is not harmful, which will not induce further corrosion and which is useful for strengthening purposes. When wax is used on an object before cleaning, care must be taken to keep the outside, which has to be cleaned, as free from the wax as possible, otherwise the cleaning solutions cannot act. Any slight amount of wax may be removed by means of petroleum spirit (benzine, petrol) and a soft cloth.

Electro-chemical Methods An electro-chemical method has already been described for removing tarnish from silver by means of aluminium and sodium carbonate, but this is not recommended for any condition other than tarnish. In its place, the zinc and caustic soda method described when dealing with bronze may be used, especially for considerable corrosion. This method, however, is not safe for thin or fragile articles. After treatment, the object should be brushed with a brush not hard enough to scratch it, and washed in repeated changes of water until free from alkali, and then dried.

Electrical Methods The purely electrical methods as described for copper and bronze may also be used for silver, and satisfactory results may often be obtained, but as a rule the chemical methods allow more latitude to fit the widely differing conditions of the silver and, if carefully chosen and carefully carried out, they give excellent results without any damage to the object.

For small repairs to silver objects, celluloid cement will be found satisfactory, and if the object is thin or fragile, or the silver not very coherent, repeated treatment with dilute celluloid solution (1 per cent.) will strengthen and preserve it.

Tin Ancient objects of pure tin are comparatively rare, and as a rule they need little cleaning beyond

that with soap and water and a brush. Occasionally, however, the object may be disfigured by concretions of calcium carbonate, which may be dissolved off by means of a dilute solution of sulphuric acid (hydrochloric acid should not on any account be used as it acts readily upon tin). From time to time the object should be taken out of the acid and brushed with a bristle brush, and when clean it should be well washed in repeated changes of water.

Tin objects are sometimes attacked by what is termed "tin pest" or "tin disease." "In the tin afflicted with the disease, there are spots of grey colour, the metal becomes brittle and the product occupies a greater vol. than the unaffected tin. The expansion produces pustule-like excrescences at the affected centres. . . . The transformation travels outwards from the spots until the whole mass is infected, and the metal readily disintegrates to a brittle powder. The disease is infectious and can be propagated by inoculation. . . ."[1] This grey modification is merely a more stable form of ordinary white tin. The transformation may be brought about by exposure to a temperature below 18° C., and hence tin objects in museums should be kept above this tempera-

[1] J. W. Mellor, *Treatise on Inorganic and Theoretical Chemistry*, VII (1927), p. 300.

ture. Tin objects in several museums have been attacked.[1]

Papyrus

This is made from the pith of the Egyptian papyrus plant. It was first employed as a writing material by the ancient Egyptians and afterwards by the Greeks and Romans.

Papyrus documents are generally very dry and brittle and sometimes impregnated with salt.

No attempt should be made to unfold or to straighten out papyrus while dry, as it would certainly break, but it should always first be damped with just sufficient water to render it pliable, which may be done by wrapping it in damp cloth or in damp white blotting-paper and allowing it to remain until the moisture has thoroughly penetrated.

Two short descriptions of the methods adopted in unrolling papyri are given by Winlock. In one case [2] " Humidors, such as cigars are kept in, were contrived, and the rolls were put into them. Then we . . . anxiously waited for sticky hot days—

[1] E. Cohen, The Physical Chemist in Search of Purity in an Impure World, *Journal Society of Chemical Industry*, 48 (1929), pp. 162–9.

[2] H. E. Winlock, The Egyptian Expedition 1924–1925, *The Bulletin of the Metropolitan Museum of Art, New York*, Part II, March, 1926, pp. 28–30.

preferably with thunderstorms—and as soon as a day promised to be unbearable, out came a papyrus and gently it was unrolled and pressed between sheets of glass. . . . Mr. Lydenberg[1] showed us how the most perilous of the old documents in the Library were mounted on almost invisible *mousseline de soie* and he had made for us the special paste needful for the work.[2] We then constructed a frame in which we could stretch *mousseline de soie* over a sheet of glass and cover it with paste. Our papyrus was laid upon the fabric and unrolled directly on it; the frame was then lifted, removing the fabric and the papyrus together from the glass; and once the paste had dried we had the papyrus both unrolled and reinforced with an absolute minimum of lost scraps and fibres." In the second case the description is as follows.[3] "Once in New York, however, the task of opening the entire roll was undertaken. By leaving it overnight in a box with damped cotton and letting the outer layers of the roll absorb moisture, in the morning we could unroll the first two or three feet, inch by inch. When the drier inner layers were arrived at and the papyrus

[1] Of the New York Public Library.

[2] The paste is believed to be of rice starch, freshly made.

[3] H. E. Winlock, The Egyptian Expedition, 1929–1930, *The Bulletin of the Metropolitan Museum of Art, New York*, Part II, December, 1930, p. 21.

began to feel brittle and crackly, the unrolling was stopped and the damp box was placed over what remained of the roll until the next day. Thus, day by day and foot by foot the great roll opened out to the end—564 cm. long (18 feet 6 inches)."

To remove salt, when present, there is only one way, namely to soak the papyrus in repeated changes of pure water until the washings when tested are free from salt. This, however, is usually only practicable for comparatively small pieces. To allow the water to penetrate freely, the papyrus should first be moistened with alcohol.[1] When the papyrus is wet great care must be taken in handling it, otherwise the ink will come off. Small pieces of papyrus are best handled by means of forceps with spatulate ends of the kind used by postage-stamp collectors. After removal from the water, it is advisable to soak the papyrus for a few minutes in two changes of alcohol; it is then placed between clean white blotting-paper and pressed until dry. The alcohol hastens drying and minimizes the tendency of the ink to come off on to the blotting-paper.

Whenever possible, papyrus should be mounted between glass, the edges of which are bound by *passe-partout*.

Papyrus may be strengthened, if required, by

[1] See footnote [1], p. 20.

treating it with a dilute solution of celluloid (0·5 per cent.), but this is rarely necessary.

Photographic developing dishes make excellent receptacles for use when soaking papyrus in water or other solutions.

When papyrus documents have been used to make "cartonnage" for mummy masks and mummy cases (a common practice in Egypt at a late date), it is often desirable to recover the documents, as some of them may be of historical value. To do this it is necessary to remove the plaster from both the upper and under surfaces of the cartonnage (the former of which is painted) and also the adhesive from between the different documents.

The underlying principles are simple. The plaster (which consists of a mixture of whiting (chalk) and glue) is dissolved off by means of a dilute organic acid (usually lactic acid or acetic acid, the former being preferable) and the adhesive is removed with hot water. Although, like most other operations, this is easy enough when one knows how to do it, in practice it requires considerable experience and patience.

The outlines of the method are as follows.[1] Put

[1] The basis of the method was kindly described and demonstrated to the author by Mr. O. Guéraud, Assistant Curator, Cairo Museum, but this has been modified in certain details as the results of various trials and experiments.

as large a piece of the cartonnage as can conveniently be dealt with on a sheet of glass.[1] Place the glass, with the cartonnage on it, in an inclined position (not too steeply inclined) resting on the bottom and against the edge of an ordinary sink, such as is found in chemical laboratories and in kitchens. Well damp the plaster by applying very hot (almost boiling) water with a small camel-hair or similar soft brush having a wooden handle. When the plaster is soaked, apply the acid in 20 per cent. strength (20 parts of strong acid to 80 parts of water) with a brush similar to that used for the water.[2] When the effervescence caused by the action of the acid on the plaster has subsided, use very hot water in quantity (preferably by pouring it on from a receptacle having a small spout, such as a jug, or from the mouth-end of a "wash bottle," such as is employed in chemical laboratories) in order to remove the dissolved and disintegrated plaster. If there is still any plaster left, as there will almost certainly be, repeat the treatment with acid and hot water

[1] Sometimes the cartonnage is placed on blotting-paper to prevent it from slipping, but, if the angle of slant of the glass is not too acute, this is not necessary, and, as blotting-paper absorbs both the acid and the products of the decomposition of the plaster, its use renders the washing of the papyrus longer and more difficult.

[2] When not actually in use, stand the brush in water.

alternately until the papyrus is clean, using, however, weaker acid (10 parts of strong acid to 90 parts of water).

When the acid is first used, it does not much matter in what manner it is applied, as the surface of the papyrus is entirely covered with plaster, but later, when this is partly dissolved and portions of the inscribed papyrus are bared, the acid should not on any account be brushed on, or the inscription will suffer (the carbon ink used being readily removed when wet), but should be allowed to trickle from a full brush on to the fragments of plaster, or should be applied to these with the tip of the brush, or should be dropped on from a small pipette or dropping bottle.

In order to remove the plaster from the under side, take a second sheet of glass and place it over the papyrus ; turn over the two sheets of glass with the papyrus between them ; remove the first (now uppermost) sheet of glass very carefully without disturbing the papyrus (which will tend to stick to the glass and from which it may gently be detached with a thin paper-knife) ; treat the fresh plaster surface alternately with acid and hot water as before.

During the treatment, numerous small fragments of plaster will usually be seen that appear to be loose and look as though they could easily be picked

off. This, however, should not be done, as the fragments are rarely as loose as they seem, but generally remain attached at some small point and, if picked off, a part of a letter or letters of the inscription may also be removed and lost (and may afterwards be seen adhering to the under side of the fragments of plaster). The only safe method of removing the plaster is with acid.

Up to this stage the work cannot conveniently be interrupted, but at this point the papyrus may be placed between blotting-paper and allowed to remain until it is convenient to continue. To make the transfer from the glass to the blotting-paper, cover the papyrus with a sheet of blotting-paper; turn the glass and blotting-paper upside-down on a table; remove the glass and, if the papyrus sticks, gently detach it as before; cover it with a second sheet of blotting-paper and then with a sheet or two of glass or other light uniform weight.

If the work is continued while the papyrus is still thoroughly wet, the different layers may be separated by the careful use of a thin and flat paper-knife,[1] an operation requiring considerable skill and patience. No force whatever should be used and if the papyrus does not readily come

[1] A celluloid paper-knife is often the best, as ivory and bone paper-knives are frequently too thick.

apart, it should be well wetted with hot water at those points where it sticks. As each layer is separated it should be placed between blotting-paper and left to dry under slight uniform pressure, and when dry mounted between glass. If the papyrus has become dry or almost dry before it is convenient to separate the different layers, it must be thoroughly well damped with hot water before the separation is attempted.

In this work there are four principal dangers to be guarded against, one being the use of too much acid (all traces of which must finally be washed out of the papyrus); another the use of too much water (or what amounts to the same thing, leaving the papyrus wet too long); a third, the use of force in taking off the plaster or in separating the different layers of papyrus; and (probably the most important of all) the use of any rubbing or friction on the wet papyrus, as the ink of the inscription (which is a carbon ink that does not penetrate the papyrus in the manner in which a modern writing ink penetrates paper, but merely rests on the surface) readily rubs off when wet.

Pictures

Pictures are of so many different kinds that no general methods of cleaning and preservation are

possible. For the consideration of the appropriate treatment they may be classified as follows: (1) Mural Paintings, (*a*) Tempera and (*b*) Fresco; (2) Paintings on Chalk (Whiting) Plaster [1]; (3) Paintings in Wax; (4) Oil Paintings; and (5) Prints and Drawings. These may now separately be considered.

Mural Paintings

The earliest pictures known are mural paintings of late Paleolithic Age and consist of drawings of animals, some in monochrome and others in polychrome, in caves in France and Spain.[2] After these in chronological order come the tomb paintings of Egypt, which constitute the largest area of mural paintings known. The earliest of these dates from the Predynastic period [3] (more than 3000 B.C.). Other mural paintings of antiquity that may be mentioned are the Egyptian temple paintings, which are common from the early Eighteenth Dynasty (about 1500 B.C.) and continue down to Ptolemaic times (332–30 B.C.); the palace paintings of Knossos in Crete (about 1500 B.C.) and later of Tiryns on the mainland opposite Crete; the palace paintings of Egypt, examples

[1] Termed "gesso" by Egyptologists.

[2] Similar cave paintings also occur in South Africa, but of much later date.

[3] Although described by the finder as a tomb, this underground room is probably not a tomb, but a shrine or chapel.

known being those of the reigns of Amenophis III (1411–1375 B.C.) and Akhenaten (Amenophis IV; 1375–1358 B.C.) respectively, though probably there were earlier ones of which no evidence has been found; the house paintings in Egypt, examples known being at El-Amârna (1375–1358 B.C.); the house paintings of Herculaneum and Pompeii, both of which towns were destroyed in the first century A.D.; the paintings in the rock-hewn temples at Ajanta in India (fifth to seventh century A.D.); and the mediæval wall paintings in Italy, England and elsewhere.

The mural paintings mentioned are of two very different kinds, which are distinguished as "tempera" and "fresco" respectively. In the former, the pigments are put on with the aid of some adhesive medium, such as glue, gum or white of egg, while in the latter the pigments are applied, without any medium other than water, to a wet plaster containing slaked lime. As the two kinds of painting require very different methods of cleaning and preservation, they will be considered separately.

Tempera Paintings

With respect to the European Paleolithic cave art, it is stated[1] that fat was employed as a medium, but it may be mentioned that the pigments used, namely, soot, red ochre and yellow

[1] M. C. Burkitt, *Our Forerunners*, 1923, pp. 177, 179.

ochre, all adhere well to limestone (the material of the cave walls) without any medium whatever, especially if either the wall or the pigment is wetted.

The only reference that can be found to the cleaning of such pictures is one by Scott,[1] in which he describes the removal from some Rhodesian prehistoric rock paintings of adherent lichens that obscured them. This was done by means of a dilute aqueous solution of ammonia, which so softened the lichens that they could be removed by gentle brushing, after which the pictures were well washed with water and then with alcohol.

Although all Egyptian mural paintings, whether in tomb, temple, palace or house, are in tempera, the ground on which the pigments are laid differs considerably. In the tombs and temples, which are practically always of stone, the paintings are done either directly on the stone, on a thin layer of gypsum plaster or on what is merely a thin coat of distemper or whitewash, which consists essentially of calcium carbonate (carbonate of lime), generally containing a trace of gypsum. This latter, however, is probably simply an impurity and not the binding material, which may have been glue (size), which has been found in

[1] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, First Report, 1921, p. 12.

specimens tested, though whether it was present as a binder in the calcium carbonate or whether it had been put on the wall separately to render the stone less porous, it is impossible to say. In the wall paintings in the palace and houses at El-Amârna, the paint is directly on the fine clay plaster with which the mud bricks of the walls are faced. In the case of the palace pavements the painting is on gypsum plaster.[1] The adhesive medium of the Egyptian paintings has not yet been satisfactorily established, glue, however, being the most probable substance.

The mural paintings of Egyptian tombs and temples are often defaced by one or more of the following, namely, dust and dirt; mud; the nests of a certain kind of bee; smoke; stains from dirty water (rain); bat excrement and whitewash, but the chief enemy is salt.[2]

[1] With respect to these pavements, Sir Flinders Petrie, who discovered them, states (*Tell el Amarna*, 1894, p. 12) that "the colours were laid on while the plaster was wet and even while it could still be moved by the brush." This suggests a true fresco, but the author has fortunately been able to analyse a specimen of the plaster, which was kindly given to him by Mr. S. R. K. Glanville of the British Museum, which proved to be gypsum containing a large proportion of calcium carbonate (a very common impurity in gypsum in Egypt) and particles of unburnt fuel.

[2] See pp. 146–7.

When the condition of the paint will allow, the superficial dust may be taken off with a soft brush, after which, if necessary, further cleaning may be done by means of petroleum spirit (benzine, petrol) or alcohol [1] applied with a small soft brush. Sometimes when the walls are salty, the paint may be in too precarious a state to permit of any cleaning.

Mud is better removed, as far as possible, in the dry condition, so as to avoid the penetration and staining of the walls that are liable to occur when liquids are employed. When in a thick layer, mud may often be partly detached by gently tapping it with a piece of wood such as the rounded end of the handle of a small brush, which if done carefully, neither damages the paint nor marks the wall. Brushing with a toothbrush or nailbrush too, is sometimes helpful, but brushes should not be used where the surface is painted, or the paint will be removed as well as the mud. Another disadvantage of a brush is that it tends to drive some of the mud into the pores of the stone or plaster and so to cause discoloration.

After the dry treatment, the mud still remaining may further be reduced in amount by careful washing with petroleum spirit or alcohol [1] applied with a small brush, the former affecting the paint and spreading the mud the less of the two. After

[1] See footnote [1], p. 20.

as much as possible of the mud has been removed in the manner indicated, careful sponging of the surface with a small damp (not "wringing wet") sponge and water should be tried. This, if done slowly and cautiously, using the minimum quantity of water and frequently rinsing the sponge and changing the water, often gives surprisingly good results, even on a painted surface.[1] It is essential, however, that the various precautions mentioned should be observed, otherwise stains and smears are produced, or some of the paint will be removed with the mud. The use of water at an earlier stage increases considerably the liability to staining.

The material of which the bees' nests are composed is largely mud, the greater part of which may be taken off by means of a small chisel-shaped piece of wood, after which a further part may be softened with water and removed with a small sponge. It will be impossible, however, to get rid of every trace. The precautions mentioned in connexion with mud should be observed, or there will be considerable staining of the walls.

It has been found impossible entirely to remove smoke or the stains from dirty water without also

[1] Red and yellow pigments, when they consist, as they usually do, of red and yellow ochre, are fairly resistant to water, as they are not merely on the surface, but have penetrated the stone or plaster.

removing the paint, but they may be lessened by careful sponging with a damp sponge and, in those places that are free from paint, such for instance as a white background, they may largely be removed by careful rubbing with very fine glass paper or emery paper. This method naturally should not be used on any part where there is paint and it must be carried out with the greatest care, otherwise the edges of the painted areas will be damaged.

Bat excrement may be lessened, though it cannot entirely be removed, by careful scraping and by washing with water to which a small proportion of ammonia has been added. Organic solvents are useless. Petrie has recently published the following description of the method adopted by him for removing bat excrement from the painted walls of a tomb. "The whole of the interior of this chamber was deeply encrusted by bats. In order to cleanse it a thick pad of cotton stuff, dripping with water, was placed on a box lid and held up against the wall by a diagonal pole on the floor. Such a pad would soften all the dirt in a couple of hours; then with a new, straight dinner-knife, the dirt could be scraped off without injuring the surface. A washing down then left the paint clear enough to be traced." [1]

[1] W. M. Flinders Petrie, *Antæopolis*, 1930, p. 13.

Whitewash, if present, has been put on in early Christian times and is usually fairly thick. It is best removed by the careful use of a knife, such as a small dissecting knife, a palette knife or a thin paper-knife, employing the blade almost flat and not scratching with the point. Acid should not on any account be employed.

Sometimes mural paintings are wantonly disfigured, and in such cases the method of treatment naturally depends upon the nature of the material used. In one instance in Egypt the walls of a number of chambers in the Temple of Rameses II at Abydos were smeared with a black material that proved to be a carbon writing ink.[1] The greater part of this was removed by sponging with water, but in places a 5 per cent. solution of sodium carbonate was used. The report states that on the whole the treatment was successful, but that in places there was a slight "*dégradation*" of the colours. The sodium carbonate appears unnecessary, and might have caused damage. The slight amount of oily matter thought to have been present could probably have been better removed by means of a solvent, such as petroleum spirit (benzine, petrol).

[1] G. Lefebvre, Sur un Acte de Vandalisme commis dans le Temple de Ramses II à Abydos, *Annales du Service des Antiquités de l'Egypte*, XII (1912), pp. 77–80.

Salt in painted limestone or sandstone may be removed by washing (after the paint has been fixed) in the manner that will be described,[1] but this is only practicable when the stone is of such a size that it can easily be handled. In the case of the painted wall of a tomb or temple, there is no way in which the salt can be extracted, even with the sacrifice of some of the paint, and the only effectual manner of dealing with it is to bottle it up and thus prevent it from doing further damage. This may be done by treating the wall repeatedly with a dilute solution of celluloid (1 per cent. dissolved in equal parts of acetone and amyl acetate), usually from three to six coats being required. As a rule a spraying apparatus cannot be employed for the first one or two coats, since the current of air created by the spray blows off particles of the paint. At first, therefore, the celluloid should be put on with a small soft brush, though not brushed on, but allowed to trickle gently from a full brush. This treatment generally brightens the colours considerably. Naturally, before applying the celluloid, the walls should be cleaned as far as possible in the manner already indicated.

The author has treated a number of tombs where the walls contained salt (also painted lime-

[1] See p. 204.

stone stelæ, lintels and statuettes [1]) in this manner, and in every case, except one, the result has been very satisfactory. The exception was one wall out of four in a deep pit tomb where there was very little natural ventilation and no ready means of producing artificial ventilation (for which reason only three coats of celluloid were applied) and where the particular wall was possibly damp. This method, however, is probably only applicable in the dry climate of Egypt and might not be satisfactory in Europe or America, where the climate is damper. An alternative to celluloid would be paraffin wax, which, as will be seen,[2] has been used in New York on blocks from an Egyptian temple. One great objection to paraffin wax on the brilliant white fine-grained limestone, such as was frequently employed for painting upon in Egypt, is that it darkens, not only the stone, but also the colours and, as the extent of the darkening varies with the nature of the pigment, the effect is not uniform, and hence the colour values of the pictures are altered. Another

[1] In the case of statuettes, this method of treatment was adopted generally, either because the object was too large or in too disintegrated a condition to be washed, but occasionally in order to make the object safe during transport, or to allow it to be stored, or even exhibited, until it could be washed.

[2] See p. 149.

objection is that wax collects dirt and the treated surface may become very unsightly.

In this connexion a brief record of what has been done by others in the way of preservative treatment of Egyptian mural paintings may be useful, and the following have been traced:

1. The paintings on the walls of tomb No. 22 (Wah) at Thebes which were rapidly disappearing owing to the powdery state of the colours were sprayed three times, first with a weak and then with a strong solution of "albumen." It is stated that this effectually fixed the colours, that no stain or darkening was caused, and that, owing to the colours being painted directly on the stone, there is no danger that the "albumen" will be attacked by white ants.[1] In the author's opinion a solution of celluloid would have been better.

2. The colours on the plaster of the El-Amârna pavement [2] were fixed by means of tapioca water, applied just thick enough to soak entirely in, leaving the surface dry.[3] In the author's opinion in this case, too, celluloid would have been preferable.

3. The painted limestone forming the tomb of Perneb, which was removed from Egypt and re-

[1] E. Mackay, Report of the Excavations and other Work carried out in the Necropolis of Thebes, *Annales du Service des Antiquités de l'Egypte*, XIV (1914), p. 89.

[2] This may reasonably be included with mural paintings.

[3] W. M. Flinders Petrie, *Tel-el-Amarna*, 1894, pp. 12–13.

erected in the Metropolitan Museum of Art, New York, was being damaged by an efflorescence of salt. Immersion in water was impossible owing to the presence of plaster, which had been freely used to fill up and conceal imperfections in the stone; and the painted surfaces of the blocks were therefore treated "in such a way as to bottle up the salts. . . ."[1] The preparation used is a proprietary one, believed to contain Chinese wood oil, resin and fatty acids.

4. Certain blocks of Egyptian limestone from the temple of Rameses I at Abydos, sculptured in low relief and originally coloured, which were too far disintegrated by salt to be washed, were also treated in New York, but in this case by being saturated with melted paraffin wax, after which they were placed in air-tight cases containing moisture-absorbing caustic potash.[2] The great drawback of paraffin wax, as already explained, is that it darkens both the stone and the pigments.

In the case of the Egyptian palace and house paintings at El-Amârna which, except for the pavements already mentioned,[3] are on clay plaster

[1] Albert M. Lythgoe, *The Tomb of Perneb,* 1916, pp. 40–2.
[2] H. E. Winlock, *Bas-Reliefs from the Temple of Ramses I at Abydos*, 1921, p. 5.
[3] See p. 141.

covering mud brick walls, the damage and deterioration is largely caused by the dryness and consequent friability of both the plaster and the bricks, but is also partly due to the loss of the chopped straw that once acted as a binder. This is generally stated to have been eaten by white ants, but some of it has possibly merely decayed. These paintings may be cleaned by first dusting with a small soft brush and afterwards washing with petroleum spirit or alcohol.[1] After cleaning, they may be strengthened by treatment with repeated coats of dilute celluloid solution (1 per cent. celluloid dissolved in equal parts of acetone and amyl acetate).[2] The paintings are on such fragile material that if they had not been covered by sand they would have perished long ago, and if they are to be left exposed any treatment can only prolong their life for a very short time. It is preferable, therefore, to remove the best fragments to a museum, which has been done in several instances. The method adopted may usefully be described. This in its broad outlines was worked out by the author as the result of numerous ex-

[1] See footnote [1], p. 20.

[2] See p. 42. Too strong a solution or too many coats of a weak solution should be avoided, otherwise the contraction of the celluloid on drying may crack the paint and cause it to stand up in curved fragments over the entire surface.

periments, but the technique was elaborated and improved by Mrs. Frankfort, who ably conducted the removal of some of the palace paintings. Dr. Frankfort's description of the removal is as follows [1]: "First the paintings were cleaned with alcohol and next sprayed with a solution of celluloid in amyl acetate; it was found that this was the only material which strengthened the fabric without spoiling the colours. When this had been done four or five times the film of paint was strong enough to stand some handling and at the same time it was waterproofed. Fine, soft cotton material was then pasted [2] on the face of the paintings, and when it was certain that all the fragments adhered, padded boards were brought up against it, and the material was nailed over the top. The boards were then supported, and the wall at the back of the paintings could with great care be broken away. It was next necessary to remove as much mud as was possible from the back of the paint, as it had no coherence and would crumble away in transport and thus leave the paint-film without support. Then the back

[1] H. Frankfort, Preliminary Report on the Excavations at Tell El-Amarnah, 1926–7, *The Journal of Egyptian Archæology, XIII* (1927), p. 218.

[2] A paste, such as a freshly-made starch paste, that can easily be removed afterwards with water, should be used, or gum might be employed instead.

of the paint was waterproofed and strengthened with celluloid and all the holes were carefully filled in with a mixture of mud and chopped straw, which we made as similar as possible to the original substance. Thus we could pour plaster of Paris on the back without the risk of its running on to the face. After this the paintings could travel safely to Cairo and London."

The mediæval mural paintings in churches and houses in England are largely in tempera.

Laurie recommends [1] that a tempera picture, if not varnished, should be cleaned with alcohol, any loose pieces being then fastened with size, which may be introduced under them with a hypodermic syringe and that finally a coat of size should be laid over the whole. The same authority suggests [1] that brittle blisters should be softened with chloroform or by a very thin solution of collodion and that a little linseed oil should then be introduced under the blister with a hypodermic syringe and the blister worked down with the fingers steeped in oil, all superfluous oil being afterwards removed.

Accounts of the cleaning and restoration of certain mural paintings, chiefly in tempera, have been published and these may briefly be transcribed.

[1] A. P. Laurie, *The Painter's Methods and Materials,* 1926, p. 229.

1. At Stobhall castle in Perthshire, tempera paintings on the wooden ceiling of a pre-Reformation chapel were scaling and the wood was attacked by the larvæ of the death-watch beetle. Acting on the advice of Dr. Alexander Scott. Mr. J. Ritchie treated the paintings with a solution of cellulose acetate dissolved in acetone, at first of 1 per cent. strength and afterwards of 2·5 per cent. strength, the solution being put on with a brush. The wood was subsequently sprayed with carbon disulphide to kill the larvæ of the beetle. The result was satisfactory and the colours were brightened.[1]

2. A tempera painting on canvas in the Chelsea Town Hall that was in danger from condensed moisture was treated by Mr. Noel Heaton, who impregnated it with wax in the manner suggested by Sir Arthur Church and used by him at the Houses of Parliament. A paste was made of white cerisine wax and toluol (1 : 4) which was applied to the previously-warmed canvas and left overnight in order to allow the toluol to evaporate. The surface was then carefully heated until the wax melted and penetrated the picture. The heating was carried out by a special apparatus devised for the purpose. After a lapse of ten

[1] J. Ritchie, The Preservation of some Tempera Paintings, *The Museums Journal*, 29 (1930), pp. 416–19.

years the condition of the painting was most satisfactory.[1]

3. Mediæval paintings on the walls of the Chapter House of Westminster Abbey,[2] probably executed in oil, required treatment on account of the surface decay of the stone on which they were painted. The pictures were first cleaned, as far as possible, from varnish (previously put on as a preservative) by means of alcohol and were then consolidated with bleached beeswax dissolved in spirit of turpentine to which linseed oil (2 per cent. of the weight of the wax) was added. The mixture was applied with a syringe. The waxed surface was then heated by means of a blow lamp fitted with a baffle plate, after which further cleaning from the old varnish was done with a mixture of alcohol and petroleum spirit (benzine, petrol) or alcohol and turpentine, or in some instances with pyridine. Wax was injected into all cavities and hollows not already filled, and before this hardened the parts were pressed with a glass muller. The surface of the painting was

[1] Noel Heaton, Encaustic Treatment of Tempera Painting in Chelsea Town Hall, 1914, *Papers of the Society of Mural Decorators and Painters in Tempera*, II, 1907–1924 (1925), pp. 74–5.

[2] Method of Preserving Mural Paintings in the Chapter House, Westminster Abbey, *The Museums Journal*, 28 (1929), pp. 375–80.

then heated and a mixture of melted wax and linseed oil painted on with a brush and the surface again heated.

4. Some thirteen years after being finished, certain commemorative mural paintings on canvas in the Administration Building of the Panama Canal were seriously attacked by fungus growths. The following mentioned treatment was found successful. The surface of the pictures was first cleaned with a solution of saponin in water and the beeswax finish removed by alternate applications of turpentine and alcohol. A 5 per cent. solution of thymol in alcohol was then applied to kill the fungus and the dead fungus was removed with a dilute solution of ammonia in alcohol. A second treatment of thymol was then given, after which a solution of paraffin wax (melting-point 56°–58° C. (133°–136° F.)) dissolved in petroleum ether (17–18 per cent. paraffin wax) to which 2 per cent. of thymol was added was applied. The restoration was completely successful.[1]

Fresco Paintings

The palace paintings at Knossos and Tiryns, the paintings at Herculaneum and Pompeii, and many of the Italian mediæval wall paintings are all true frescoes, and since in a fresco the pigment

[1] A. B. Newman, Restoring the Panama Mural Paintings, *Cooper Union Bulletin*, No. 2, 1930. Also *Journal of Chemical Education*, 7 (1930).

is surrounded by a pellicle of calcium carbonate (carbonate of lime) that acts as a binder, a fresco from its very nature will stand methods of cleaning that would be fatal with tempera paintings. Writing of the Tiryns frescoes, Noel Heaton states [1] that (1) "The surface of the painting can be immersed in water and even scrubbed without injury . . ."; and (2) "The painting can be boiled without injury in water, caustic soda, ether, alcohol, benzene and other solvents . . ."

With respect to the cleaning and restoration of true frescoes, Church recommends,[2] first, cleaning by careful brushing, and afterwards with alcohol applied on cotton, then the renewing of any lost colour in tempera and finally the preservation by coating the surface with a special paraffin wax mixture. This, which has the consistency of an ointment, is made by melting together 4 parts of hard paraffin wax (melting-point above 65·5° C. or 150° F.), 1 part of spirit of turpentine, and 15 parts of toluol. The mixture is spread cold over the surface of the fresco, allowed to remain until the turpentine and toluol have evaporated, when the wax is melted by heat and driven into

[1] Noel Heaton, On the Nature and Method of Execution of Specimens of Painted Plaster from the Palace of Tiryns, in *Tiryns II*, by G. Rodenwalt, 1912, pp. 216.

[2] Sir A. H. Church, *The Chemistry of Paints and Painting*, 1915, pp. 356–7.

the painting. A fresco in St. Stephen's Church, Dulwich, was treated by Church in this manner, and four years later was reported to be in a perfectly sound condition.

In this connexion it may be mentioned that Pliny [1] recommends the use of a special kind of beeswax to prevent vermilion paint from being injured by exposure to the sun or moon. The directions given are that the wax should be melted down with oil, applied hot with a brush, heated by means of a brazier, rubbed with wax candles and polished with a cloth.

Paintings on Chalk (Whiting) Plaster

An outstanding example of pictures on chalk (whiting, whitening) plaster [2] is the painted casket found in the tomb of Tut-ankhamūn,[3, 4] which is a very ordinary wooden box coated on the outside with chalk plaster (i.e. whiting and glue) on which, exquisitely painted in colours, are miniature battle and hunting scenes, the whole being covered with a thin layer of varnish, originally colourless, but now yellow with age. When taken from the tomb, the box was coated with white limestone dust,

[1] *Natural History*, xxxiii, 40.

[2] Termed "gesso" by Egyptologists.

[3] Howard Carter and A. C. Mace, *The Tomb of Tut-ankh-Amen*, i, 1923, pp. 110–11, 165–6; Plates XXI, L–LIV.

[4] Howard Carter, *The Tomb of Tut-ankh-Amen*, ii, 1927, pp. 17–19; Plate III.

especially on the lid, and in a few places there were splashes of mud. The dust was removed with a soft brush and the mud by means of damp cotton-wool, after which the surface was cleaned with petroleum spirit (benzine, petrol) applied with a small brush. A number of blisters on the plaster were then filled with paraffin wax, which was done by introducing under them by means of a small pipette a warm saturated solution of the wax in petroleum spirit, the surplus wax being removed while soft with petroleum spirit and a brush. Small fragments of the plaster, that were loose or had fallen off, were fixed in place with celluloid cement, after which the whole surface was sprayed with a dilute solution of celluloid. Some weeks later it was noticed that the wood of the box was warping (owing to the difference in temperature and humidity between the tomb and the workshop) and that in consequence the painted plaster was in great danger of breaking off. The box, therefore, was treated with a thick coating of hot melted paraffin wax, which consolidated and fixed the plaster. Before the box was exhibited to the public, the surplus wax was removed by means of heat. So far as can be seen, no deterioration has taken place since the box has been in the Cairo Museum, now several years.

One drawback of the wax treatment has been that if at any time it is wished to remove the old discoloured varnish in order to see the pigments in their original colours and brilliancy, what would have been a very simple matter (the varnish being readily soluble in alcohol) has been rendered difficult, as now the wax would also have to be removed, which would be by no means easy.

Other examples of painting on chalk plaster are certain wooden coffins, wooden canopic boxes and wooden stelæ from ancient Egypt, and though few, if any, of these can be called pictures, they may be dealt with in this connexion. In every instance the painting is in tempera, in some cases being varnished and in others without varnish. This varnish (often very badly applied and far from uniform in thickness), although it may be proved to have been originally colourless or practically colourless,[1] is now yellow where the layer is thin and red where the layer is thick, and looks very ugly. No case is known to the author in which these Egyptian objects have been treated like oil paintings and the old varnish removed and replaced by a thin uniform film of modern varnish that would enable the pigments to be seen in their original colours and brilliancy, but this would be

[1] A. Lucas, *Ancient Egyptian Materials*, 1926, p. 153.

a very simple matter, as the old varnish consists of resin easily soluble in alcohol and the objects would gain much in appearance by the treatment.

When the surface is varnished, there is no difficulty in removing ordinary dust and dirt, which may be done with a damp sponge or with petroleum spirit (benzine, petrol), but if water is used excess should carefully be avoided, as there is always risk of its penetrating through cracks to the plaster, which is very susceptible to the action of water and quickly disintegrates. Alcohol cannot be used as it would remove the varnish.

Where the surface is unvarnished, petroleum spirit is the only safe medium to use, as with alcohol there is always danger of some of the paint coming off, and with water not only would the paint be removed, but the plaster would also be destroyed.

In the case of unvarnished objects the plaster may be strengthened and the paint made to adhere better by repeated treatment with a dilute (1 per cent.) solution of celluloid, and repairs may be made with celluloid cement. On such objects it is not safe to use paraffin wax, as it darkens both the plaster and the pigments.

With varnished objects, paraffin wax may be employed, if it is not put on too hot, as consider-

able heat melts the varnish causing it to shrivel and look very ugly. As an unvarnished object, after treatment with celluloid solution, is in a similar condition to a varnished object, it may usually be treated with paraffin wax without ill effects. Repairs may be made with celluloid cement.

Paintings in Wax

This method of painting is mentioned by Pliny,[1] who terms it encaustic painting. The examples of the art that have survived from antiquity are very few, being limited to about 100 portraits of the Roman Age (second and third centuries A.D.), mostly on wood, but a few on canvas, discovered by Sir Flinders Petrie in the Fayum province of Egypt, which have been distributed to various museums.

A certain amount of cleaning and restoration was done to these portraits when they were found, as Petrie writes[2]: "The mere accumulation of dirt . . . is easily cleaned off. Both water and spirit can be used freely for rubbing these wax surfaces without injury." "There is no preservative so satisfactory as flooding over with melted paraffin wax; this must be hot enough to penetrate the cracks freely, but not so hot as to melt the ancient wax paint." "Where the changes have

[1] *Natural History*, xxxv, 31, 39, 41.

[2] W. M. Flinders Petrie, *Roman Portraits and Memphis* (IV), 1911, p. 6.

been less . . . then a thin coat of paraffin has been added by spreading over the face and rubbing into the cracks a soft butter of paraffin and benzine. . . . As the benzine evaporates the paraffin can be gently melted into the cracks."

It seems possible that further treatment was given to some of the portraits that are in the National Gallery and in the Victoria and Albert Museum respectively, though the remarks about to be quoted, which are very ambiguous, may have reference to Petrie's original treatment. Church states [1] that "The wax having become disintegrated in the course of centuries has been remelted, some fresh wax having been added in several instances," and Laurie says [2]: "Not only were certain repairs necessary on them by remelting the wax . . ."

One such portrait found subsequently, that was in such an exceedingly bad state of preservation that it was difficult to see any details, was submitted to the author for treatment. The superficial dust was first removed with a camel-hair brush and the surface then cleaned by means of alcohol applied with a similar brush. The use of

[1] Sir A. H. Church, *The Chemistry of Paints and Painting*, 1915, p. 80.

[2] A. P. Laurie, *The Painter's Methods and Materials*, 1926, p. 171.

a damp sponge or rag or of water in any form would have been dangerous, as, where the paint had fallen off, the water would have had access to the wood and would probably have caused warping. Fixing the loose paint with melted paraffin wax was tried in one corner of the picture, but was not satisfactory and was abandoned, as the wax so darkened the wood in those parts where the paint was thin or missing that all detail of the painting was lost. The paint was finally fixed by means of a 1 per cent. solution of celluloid dissolved in equal parts of acetone and amyl acetate.

Oil Paintings

When reference is made to the cleaning and preservation of oil paintings, valuable works by the great masters are at once thought of and with respect to these the suggestions made by a Committee of the Royal Academy [1] may be quoted.

1. "The cleaning of old pictures is a work requiring not only fine manual skill, but nice judgment derived from knowledge of the methods of the artist, of the constituents of the priming, pigments, mediums and varnishes that he employed and of the chemical action of solvents on these. It also requires a trained artistic sense, which can estimate the gain or loss likely to result from any attempted cleaning. These qualifications cannot be expected from the inexperienced and a rash

[1] Public Press.

experiment may, in a few minutes, destroy a masterpiece."

2. "The decision to clean or repair an irreplaceable work of art ought not to rest on the judgment of a single mind, but should be a matter for open consultation with artists and scientists, who have specially studied the subject. No countenance should be given to secret methods. If a method of treatment is kept secret any injury due to its failure is a dead loss, since no experience is acquired by which a similar disaster may be avoided; and at the same time the resources of modern chemistry and physics are debarred from the service of art. It should be a professional point of honour with the operator to make no concealment of his materials or methods from the owner or custodian of a picture, which has been entrusted to him for treatment. Every custodian of a public gallery should be fully acquainted with the details of the process of repair and hold himself absolutely free to discuss them with artists, scientists and others whose knowledge may be of service."

One of the conclusions adopted by the International Conference for the Study of Scientific Methods for the Examination and Preservation of Works of Art [1] is to the same effect, namely:

[1] *Mouseion*, Vols. 13–14 (1931), p. 165.

"That no picture should be cleaned or restored without full preliminary examination by scientific methods and photography, and that a full record of all operations be kept, both by means of photography and in writing. That before restoration of a picture, it is desirable that the opinion of a corporate body of qualified experts should be taken."

In a letter signed by forty-three Members of the Society of Mural Decorators and Painters in Tempera addressed to the President of the Royal Academy [1] a number of suggestions are made relative to the cleaning and restoration of pictures, several of which are incorporated in the recommendations of the Committee of the Royal Academy already quoted, but in addition are the following statements :

"That great and irreparable damage, at the hands of picture restorers, has recently befallen some of the noblest pictures in Continental Galleries is a fact of which we are fully convinced . . ."

". . . we are naturally apprehensive lest the infection of the procedure, which has caused such havoc abroad, should spread to our own country."

"We believe that the removal of the varnish or other surface of a picture is always a dangerous process, and that in every case in which an artist

[1] *Papers of the Society of Mural Decorators and Painters in Tempera*, II, 1907–1924 (1925), p. 90.

has used any method of varnish painting, removal of the surface inevitably falsifies his original intention. Many of us have vividly in mind instances in which the unequal removal of the surface has completely[1] subverted the tonality of the picture."

In view of the above pronouncements, no attempt will be made to indicate modes of treatment for masterpieces, but there are many oil paintings that are not masterpieces and yet need and merit attention and a few simple methods may be given for cleaning off the dirt and old varnish from paintings that are not of first-class importance, a duty that sometimes falls to the lot of the amateur.

Complete treatment of oil paintings which are generally on canvas, but may be on wood, may include cleaning, relining, repairing, retouching, and revarnishing.

To clean accumulated dirt and smoke from an oil painting, the best reagent is a 1 per cent. solution of saponin in water,[2, 3] which is quite

[1] Printed "complete", evidently a printer's mistake.

[2] Saponin is a white powder obtained from the common soapwort (*Saponaria officinalis*); it is soluble in water and causes a frothing when the water solution is agitated, for which reason it is often employed as a foam-producer for beverages.

[3] This was first brought to the author's notice as a cleaning reagent for pictures by Sir Robert Robertson, F.R.S.; it is recommended by Professor Laurie (A. P. Laurie, *The Painter's Methods and Materials*, 1926, p. 231).

harmless unless excess is used or unless allowed to remain on too long, when the water might penetrate to the canvas and cause damage. The saponin is applied by means of a pad of cotton-wool, which is damped (not soaked) in the solution. Soap, though often recommended, should not be used.

An alternative, and also safe method, though not so satisfactory, is by means of breadcrumb applied in the manner of an indiarubber. This is advocated by Church, who describes it as follows [1]: " . . . a loaf of household bread, not more than a day old, should be taken and its crumb broken up into a tin canister furnished with a lid; it is important that no pieces of crust and no fragments of crumb which have become hard by drying, should be introduced. Then the crumb should be shaken out, in portions at a time, on to the varnished surface and rolled gently thereon by means of the fingers. By repeating this operation until fresh crumbs no longer become discoloured, it is often possible to improve the appearance of a picture very gently."

The removal of the superficial dirt, however, is only the first step in the cleaning and is preliminary to the next stage, namely, the removal

[1] Sir A. H. Church, *The Chemistry of Paints and Painting*, 1915, pp. 352–3.

of the varnish, which is generally cracked, discoloured and largely opaque.

Picture varnishes are of two principal kinds, namely (*a*) those consisting of resin (often mastic) applied in the form of a solution in a volatile solvent (generally turpentine), and (*b*) those consisting of resin dissolved in a drying oil (now generally linseed oil, though formerly often walnut oil or poppy seed oil), to which a volatile solvent (turpentine) has been added as a thinning material.

Varnishes of the former class are readily soluble in alcohol,[1] which may be used to remove them, but those of the latter class are less soluble and often require special methods, which vary with the nature of the varnish. In no case, however, should the strong alkalies, potash and soda, be used, and even the less powerful alkali ammonia, although frequently employed, is not without action on the paint. A less dangerous and good solvent may be made from ammonia and balsam of copaiba.[2] This is prepared by adding strong ammonia, drop by drop, to the balsam and shaking until a clear solution, with a very faint smell of ammonia is obtained. After the use of this solution, the picture is finally carefully washed with turpentine.

[1] See footnote [1], p. 20.

[2] A. P. Laurie, *The Painter's Methods and Materials*, 1926, pp. 234–5.

Sometimes, as in Florence, the best picture cleaners avoid the use of solvents altogether and scrape off the old varnish with a knife,[1] an operation requiring considerable skill and care.

The alcohol, or other solvent employed, is applied either by means of cotton-wool or with a brush, the latter being preferred by Laurie.[1] The best strength of alcohol, according to Church,[2] is that containing about 70 per cent. of absolute alcohol by volume, which is the rectified spirit of the British Pharmacopœia diluted with one-quarter of its volume of water. If it is feared that the solvent is acting too vigorously, the action may be restrained, or altogether arrested, by means of turpentine and the professional picture cleaner often uses the solvent and the restrainer alternately. Linseed oil or castor oil[3] may also be used as a restrainer, the objection to the latter being that it is not a drying oil and, therefore, must be removed when its purpose is fulfilled, which may be done with turpentine. One danger, and a very real one, to be guarded against in picture cleaning is over-cleaning and it is much better

[1] A. P. Laurie, *The Painter's Methods and Materials*, 1926, pp. 234–5.

[2] Sir A. H. Church, *The Chemistry of Paints and Painting*, 1915, p. 354.

[3] A. P. Laurie, *The Painter's Methods and Materials*, 1926, p. 234.

that a little of the old dirt or old varnish should be left on the picture than that any of the paint should be taken off. Another danger is that, if there is over-painting on the top of an original picture that had been varnished, this may be removed by the solvent, but fortunately it is generally desirable that over-painting should be removed and the original work made manifest.

By the relining of a picture is meant, not the replacement of the old canvas by new, but merely the backing of the old canvas with fresh canvas, leaving the former still in place. A common method of attaching new canvas is by means of glue or of a mixture of glue and resin,[1] but glue in a damp climate is unsatisfactory on such a material as canvas, and de Wild recommends[2] the use of beeswax instead, the process being carried out as follows. The face of the picture is protected by being covered with a number of layers of fine tissue-paper, which are pasted on with starch paste; when the paper is dry, the picture is turned over on to a thick pad of cotton-wool or other soft material and the fresh canvas is laid in position on top of the old; very hot melted beeswax is now spread over the new

[1] A. P. Laurie, *op. cit.*, pp. 235–6.

[2] A. Martin de Wild, *The Scientific Examination of Pictures*, 1929, pp. 88–9.

canvas, which it partly penetrates, but which it is made to penetrate further by being carefully heated with an electric iron, so that it is driven, not only through the new canvas, but also through the old into the paint layer, which it consolidates. Care must be taken that the iron is not too hot or the paint may be damaged. The ironing also serves to flatten the new canvas and to take out any creases. After the wax has thoroughly cooled, the paper is removed by means of a damp sponge and any wax that has penetrated through to the front is taken off with turpentine. It is stated that Dr. Theodor Krause, of Dresden, who has recently restored Raphael's "Sistine Madonna," employed a mixture of beeswax and resin.

Any necessary repairs to a canvas are carried out at the time it is relined. Where there are rents, but no parts missing, the torn edges are brought as closely together as possible before the tissue-paper is put on and, if necessary, are further adjusted from the back when the picture is turned over. If there are holes in the canvas, these are filled in from the back with loose patches made to fit before the new canvas is put in place and, when the wax is applied, these patches become fixed.

After the repairing and relining, and before the revarnishing, any paint missing from the damaged portions or from any scratches, must be replaced

by fresh paint, but before this can be done, the gaps in the surface through which either the old canvas or the new canvas shows, must be filled in with a ground material (stopping), which is usually either plaster of Paris or chalk (whiting) and glue, on which the painting can be done. This operation and that of retouching are manifestly matters to be left to an artist. The picture is finally revarnished with mastic varnish.

Oil paintings, whether on canvas or on wood, require constant attention if they are to be kept in good condition. The atmosphere of the room in which they are exposed should not be damp nor too dry and the temperature should be neither too hot nor too cold and, above all, it should be as equable as possible. Direct sunlight should be avoided, and even reflected light should not be too strong.

The wood of painted panels is liable to be attacked by the larvæ of certain beetles, the best remedy for which is fumigation with carbon disulphide,[1] which when pure has no deleterious action on the paint. After fumigation, the exit holes of the mature beetle should be filled up with melted beeswax or with a mixture of beeswax and rosin (beeswax 3 parts and rosin 1 part).

[1] Other insecticides are not recommended, as the action of many of them on paint has not been tested.

Prints and Drawings

The principal ailment from which prints, including engravings and etchings, suffer, is a discoloration (caused by mildew) of the paper on which they are executed, which, however, may be removed by suitable treatment. To do this, first any loose dust present is taken off by means of a soft dry brush; then, unless the discoloration is considerable and provided the weather conditions are favourable, exposure to the sun should be tried, as, if successful, it is much safer than the use of chemicals. Under Egyptian conditions, this method often gives very satisfactory results, but naturally it cannot be applied in the absence of strong sunlight. For this, the print is placed in a shallow dish containing water and exposed to strong sunlight for several hours. It is essential that the print should be entirely covered with water during the whole of the time, as sunlight causes paper when dry to become discoloured and brittle. When free from discoloration, the print is removed from the water, blotted with clean white blotting-paper and then placed between fresh blotting-paper and subjected to gentle uniform pressure until quite dry.

If the mildew is considerable, the sunlight treatment, although it will improve the appearance of the print, may be insufficient to remove all discoloration, in which case a bleaching agent must

be employed. This may be (*a*) hydrogen peroxide, (*b*) bleaching powder with hydrochloric acid, or (*c*) sodium hypochlorite with hydrochloric acid. Of these three agents,[1] hydrogen peroxide is the safest, though it is the most expensive. The ordinary commercial form is a water solution, which is sold in different strengths.[2] For use, a mixture is made of hydrogen peroxide solution (10 vols.) and water in equal proportions, in which the print is immersed until clean, when it is taken out, washed well in repeated changes of water and dried with blotting-paper as already described. Another mode of applying hydrogen peroxide is in alcoholic solution, equal quantities of the reagent and of absolute alcohol being mixed and painted on the discoloured spots or patches with a soft brush.[3] Hydrogen peroxide is by no means instantaneous in its action, but always requires a considerable time to do its work and in some

[1] A fresh reagent, chloramine-T, has recently been recommended by Dr. Plenderleith, of the British Museum. This is used in 2 per cent. aqueous solution with an interval of a day between each application (H. J. Plenderleith, Laboratory Notes, *The British Museum Quarterly*, III, 1928, p. 84).

[2] 10, 20, 40 volumes, etc. (about 3, 6 and 12 per cent. respectively, the volumes indicating the yield of oxygen when decomposed).

[3] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, Third Report, 1926, p. 5.

cases it is best left overnight. In whatever manner hydrogen peroxide is used, it acts better when warm and the dish containing the print should be allowed to stand for several hours in a warm place, or if the reagent has been applied with a brush, a warm (not hot) electric iron should be moved over, but not quite touching, the surface. Before use the hydrogen peroxide should be tested with litmus paper and, if found acid, as is often the case, the acidity should be neutralized by the careful addition of a small quantity of a dilute solution of ammonia. This not only makes the reagent safer in use, but also produces a more satisfactory liberation of oxygen.

For methods (*b*) [1] and (*c*),[1] the print is first immersed, face upwards, for about 20 minutes in a 1 per cent. solution of hydrochloric acid (made by diluting the strong acid with about 30 times its volume of water),[2] then transferred without washing for another 20 minutes to a second bath containing either a dilute solution of bleaching powder [3] (1 gram to 100 c.c. of water: 1 ounce to 100 fluid ounces of water) or of sodium hypochlorite [3] (0·5 gram to 100 c.c. of water: half an

[1] These are the usual methods employed by professional picture cleaners.

[2] The strong acid as sold (specific gravity 1·17) contains about 28 to 32 per cent. of hydrochloric acid gas.

[3] This must be fresh as it deteriorates quickly when kept.

ounce to 100 fluid ounces of water), then back again to the acid (without washing), and so on until the discoloration disappears, when finally the print is thoroughly soaked in repeated changes of distilled water until no trace of acid can be found on testing. This method gives very satisfactory results, but possesses one great drawback, namely, the difficulty of getting rid of the last traces of the chemicals employed and very thorough washing is essential. Sometimes placing the print between dry blotting-paper and ironing it on the back with a warm (not hot) iron improves its appearance.

Porcelain photographic developing dishes make excellent receptacles for use when immersing prints in a solution of any sort. When water, or water solutions are used, it is preferable, instead of putting the print directly on the bottom of the dish, to lay it on a thick sheet of plate glass slightly smaller than the dish, so that in removing it from the water it may be lifted out on the glass without being touched, wet paper being very tender and easily torn. In the absence of a glass plate, the water should be poured off carefully and the print left in the dish until nearly dry, when it may be handled without danger.

There are two important points to which attention may be directed, first that in putting the

print into the solution, bubbles of air on the surface should be avoided, or, if these form, they should be removed, which may easily be done with a small camel-hair or similar brush. The second precaution is that great care must be taken in washing the print, as a rush of water from a tap, or too strong a flow, may tear the paper. A gentle stream of water allowed to flow through the dish from a small rubber tube, the end of which is under the glass plate, is a very satisfactory method of washing.

In addition to discoloration by mildew, prints may be accidentally stained in various ways; for instance, by oil, grease, or ink, all of which, however, may be removed by appropriate treatment, which is best applied before the removal of the mildew.

The simplest way of removing oil or grease is first to apply a small pad of cotton-wool damped in petroleum spirit (benzine, petrol) to the stain and so remove most of it, and then to soak the print in the petroleum spirit, the solution of the stain being expedited if the print is placed face downwards in the liquid and the back gently brushed from time to time with a soft brush. If the stain is very persistent and is not removed, or not easily removed, by petroleum spirit, acetone should be tried, since animal and vegetable oils,

(not mineral oils) are more easily soluble in the latter than in the former. For the removal of oxidized oil, paint or varnish, Scott recommends pyridine applied by means of a brush of glass fibre.[1]

The method of removing ink stains varies with the nature of the ink. Carbon ink (Indian ink, drawing ink) may be removed with warm water and gentle brushing. Old iron ink, without any provisional blue colouring matter, may be removed by brushing on hydrogen peroxide or a small quantity of a dilute solution of oxalic acid (10 per cent.) or tartaric acid (10 per cent.), allowing it to remain a few seconds, soaking up the excess with clean white blotting-paper, repeating the application if necessary, and finally washing, by applying a little water several times and each time soaking it up with blotting-paper. Stains made with a modern blue-black ink, which is an iron ink containing a blue colouring matter, generally an aniline dye, may be removed by hydrogen peroxide or by applying alternately oxalic acid (10 per cent.) or tartaric acid (10 per cent.) and a dilute solution of bleaching powder (1 per cent.) or of sodium hypochlorite (0·5 per cent.), the

[1] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, First Report, 1921, p. 6; Third Report, 1926, pp. 5–6.

excess solution being soaked up with blotting-paper and the spots finally well washed with water in the manner already described.

As a rule, when a print is stained by mildew, the fungus that has caused the damage is dead and the effects of its activity may be removed by one or other of the methods described, but sometimes the fungus is alive and it may be desirable to kill it without subjecting the print to chemical treatment. In such a case, fumigation with thymol as recommended by Scott,[1] is the best method. This is carried out by placing the print in a fairly air-tight box, in which is a small dish containing thymol fixed above a small electric lamp, which when lighted vaporizes the thymol, which kills the fungus.

Drawings and water-colour paintings often become discoloured on account of the white lead pigment (flake white) used having been exposed to the action of sulphuretted hydrogen, which is often present in small proportion in the atmosphere, and which acts chemically upon white lead, forming sulphide of lead, which is brown, grey or black according to the severity of the action. The dark-coloured sulphide may be converted into white sulphate of lead (which therefore does not show),

[1] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, Third Report, 1926, p. 7.

by the use of hydrogen peroxide. As the usual water solution of this reagent would be unsuitable in the case of water-colour paintings, pastels, charcoal and pencil drawings, which would be ruined by water, Church recommends [1] an ethereal solution. This, too, has been used by Scott,[2] who also employs the same alcoholic solution he uses for mildew.[3] The solution is applied with a small brush. To make the ethereal solution the aqueous liquid is shaken up with an equal quantity of ordinary ether and the ethereal solution that floats on the top of the mixture is decanted off for use. A warm (not hot) electric iron moved over, but not quite touching the surface, expedites the reaction. The same method may be applied to blackened white lead on illuminated manuscripts.

Plaster

Modern plaster is of many different kinds, but anciently the number of varieties was less, the principal ones being gypsum plaster; plaster made from chalk (whiting, whitening); lime plaster and clay plaster, all of which may some-

[1] Sir A. H. Church, *The Chemistry of Paints and Painting*, 1915, p. 151.

[2] Dr. Alexander Scott, *op. cit.*, Third Report, pp. 4–5.

[3] Dr. Alexander Scott, *op. cit.*, p. 5.

times require treatment and therefore may be considered.

Gypsum Plaster

Gypsum plaster consists of natural hydrated calcium sulphate (sulphate of lime) that has been burnt, powdered and slaked with water, the modern finer qualities being known as "plaster of Paris." It was employed extensively in ancient times, particularly in Egypt, where it was used (*a*) for repairing faulty places in tomb walls; (*b*) often for coating tomb walls before painting; (*c*) for modelling the heads (except those that were gilt or that were made of cartonnage) sometimes placed on coffins during the Roman period; (*d*) for making moulds and casts; and (*e*) for mortar. Gypsum plaster was also used in both ancient Greece and ancient Rome, as Theophrastus [1] (fourth century to third century B.C.) and Pliny [2] (first century A.D.) describe its nature and preparation.

In mediæval Italy and Spain, gypsum mixed with glue water was employed by artists to produce a ground for painting upon, which was termed *gesso*, an Italianized form of the Latin word *gypsum*, which latter is derived from the Greek *gupsos*. The term *gesso* in Italian, however, may also mean any kind of gypsum or gypsum

[1] *History of Stones*, CXI–CXIX.
[2] *Natural History*, XXXVI, 59.

plaster. According to Cennino Cennini [1] (fifteenth century), gesso was of two kinds, *gesso grosso*, which was unslaked gypsum, and *gesso sottile*, which was slaked gypsum, both being used with glue. By Egyptologists the term "gesso" is now commonly used to mean a plaster made with chalk (whiting, whitening) and glue.

Chalk plaster, which as just stated is termed "gesso" by Egyptologists, consists of finely-divided chalk (whiting, whitening), which by itself has neither cohesive nor adhesive property, mixed with glue water as a binder. It was largely used in ancient Egypt for applying to wood as a ground for painting and gilding, often being worked or inscribed in low relief before being gilt. It was also used to cover the cartonnage mummy masks and coffins made from old papyrus documents. Theophilus, a Greek writer of about 300 B.C., refers [2] to the use of both slaked gypsum and glue, and chalk and glue for coating skins as a ground for painting, and Church states [3] that "The ordinary ground for Italian and Spanish tempera-paintings consisted either of whitening

[1] A. P. Laurie, *The Materials of the Painter's Craft*, 1910, pp. 189–92.

[2] *Ibid.*, pp. 157, 159–60.

[3] Sir A. H. Church, *The Chemistry of Paints and Painting*, 1915, pp. 22–3.

and size or of burnt gypsum . . . mixed with size." This use of two different materials for the same purpose and the application of the same name, "gesso," to both, is very confusing. Thus also the *New English Dictionary* gives the meaning of the Greek word *gupsos* as "chalk, gypsum," which are not synonyms, but two entirely different materials with very different properties, and Church writes [1] "Gesso, made of plaster of Paris and size, or of whitening and size. . . ."

Lime Plaster

Lime plaster is the groundwork of true fresco as employed for mural decoration. It was used at Knossos in Crete about 1500 B.C.[2, 3] and at Tiryns on the mainland opposite Crete somewhat later [4]; it was also employed in Pompeii and Herculaneum and by the artists of the Italian Renaissance. In true fresco painting the pigments were (and still are) applied, without any other medium than water, to a damp surface contain-

[1] Sir A. H. Church, *op. cit.*, p. 32.

[2] Noel Heaton, "Mural Paintings of Knossos," *Papers of the Society of Mural Decorators and Painters in Tempera*, II, 1907–1924 (1925), pp. 17–34.

[3] Noel Heaton, "Minoan Lime-Plaster and Fresco Painting," *Journ. Royal Inst. of British Architects*, XVIII (1911), pp. 697–710.

[4] Noel Heaton, "On the Nature and Method of Execution of Specimens of Painted Plaster from the Palace of Tiryns," in *Tiryns II*, G. Rodenwaldt, 1912, pp. 211–16.

ing caustic lime and become incorporated with the lime and harden with it.

Clay Plaster

Clay, often mixed with straw, was sometimes used in ancient Egypt as plaster for covering the limestone walls of tombs, being frequently, though not always, coated with a thin layer of white plaster before painting; it was also employed for covering mud brick walls before they were painted, as for example at El-Amârna, where the painting was done directly on the clay plaster.

Treatment

As the various kinds of plaster mentioned are all employed as grounds for painting, the methods of treatment required to clean and preserve them have already been described in connexion with pictures, but the chalk and glue plaster when used as a base for gilding has not yet been dealt with, which may now be done.

This plaster is soft and easily injured mechanically; it is also readily disintegrated by water; the principal damage it is subjected to, however, arises from the alteration in volume of the wood to which it is attached, contraction of the wood caused by drying resulting in some of the plaster becoming partly detached or wholly breaking off, especially at the edges and along any cracks or joints.

The gilt on such plaster should first be dusted with a small soft brush and then cleaned by means

of warm water applied with a small sponge or soft cloth, or, if the gold is discoloured, with a dilute solution of ammonia in water (10 parts of strong ammonia to 90 parts of water). Great care is necessary to prevent the water from entering any cracks or from penetrating underneath the gilt, as this would disintegrate the plaster, which in a few minutes would become of the consistency of soft mud.

For plaster in bad condition, there is only one satisfactory method of consolidation, namely, treatment with very hot melted paraffin wax, which is naturally done after cleaning and when the object is perfectly dry. The method of applying the wax depends upon the nature, size and condition of the object. As a rule, it will be better to paint on the wax, which must be very hot, with a flat hog brush, so that it may fill up any cracks and may penetrate as much as possible below the gilt surface. If, however, owing to the wood having shrunk, some parts of the plaster are partly detached, or if there are blisters, it will be necessary to introduce wax behind the loose pieces and into the blisters, which are then pressed firmly back into position with the hand and are held in place until the wax has cooled sufficiently to become fixed. The wax may best be introduced into the cavities by means of a

pipette or it may be poured in from a vessel with a spout, such as a small metal can or teapot. Usually some suitable entrance aperture for the wax will exist, but, if not, one must be made, either by enlarging an existing aperture or by making a fresh one, which needs care, otherwise an ugly scar will be left. Sometimes a sharp penknife will be found a sufficient tool, but at other times a drill will be required. In order that the wax filling should not run out as fast as it is poured in, the wax should not be too hot and any holes or cracks through which it might escape should be well plastered over with wax which is just on the point of solidification, this being taken off again later. An ordinary funnel is not of much use in pouring in the wax, as it constantly becomes blocked by the wax congealing (if the wax is sufficiently hot to keep the passage clear, it is too hot for the work), but a jacketed copper funnel, having the jacket filled with hot water, of the kind used in chemical laboratories, may sometimes be helpful.

Repairs, that is to say the replacing of fragments that have become detached, may also be carried out with wax, the object to be treated if possible being laid horizontally while this is done, as to stick loose pieces satisfactorily on to a vertical surface with hot wax (wax not being an

adhesive until it cools) is most difficult. To carry out the repairs, a little hot wax should be painted on the bare patch with a brush, then the loose piece should be taken up with forceps, plunged into the hot wax and placed in position, where it is held until the wax has cooled sufficiently to fix it.

All surplus wax may be removed from the surface of the object by heat in the manner already described. This, however, is by no means an easy matter where fragments have been refastened with wax or where wax has been introduced beneath the surface, either to fix portions that have come away from the wood or to consolidate blisters, as when the surface is heated to remove the surplus wax, that used for the repairs melts also, unless the work is done slowly and carefully. An electric heater is to be preferred, whenever choice is possible. As already mentioned, the writer removed the excess wax from the four gilt shrines that enclosed the sarcophagus of Tutankhamūn (a total surface area of about 2,660 square feet) by means of small electric heaters, the melted wax being wiped off with soft cotton waste. The sections of the shrines were supported in a horizontal position during treatment, so that the wax from under the plaster, even if it melted, should not run off. Great care was required with

some of the roof sections, which were not wholly gilt but partly covered with black resin varnish that blistered when strongly heated.

Pottery

By pottery is meant vessels and ware made from clay and then hardened by being baked; it may be either glazed or unglazed; Egyptian faience and porcelain are not included.

Pottery is very resistant to the ordinary processes of decay, its weakness lying in its fragility and porosity, the latter being characteristic of unglazed pottery.

The fragility of pottery allows it to be easily broken and the porosity permits it to become impregnated with various substances, for instance fatty matter (in the case of jars containing fat) or salts from salty ground, which latter may ultimately cause disintegration if the salts should have an opportunity of crystallizing.

Pottery is sometimes disfigured by incrustations of calcium carbonate or calcium sulphate, or both, derived from wet ground containing these substances.

As a rule the first step towards cleaning pottery is to wash it well with water and a soft brush. If salt is present the object must be soaked in repeated changes of water until all the salt is

dissolved out. This will take some days, and possibly several weeks.

Fatty matter may be removed by soaking in petroleum spirit (benzine, petrol), but the object must be dry before treatment.

No attempt should be made to remove either calcium carbonate or sulphate by scraping, as this would not only be useless, but would scratch or disfigure the object. Calcium carbonate may be removed by brushing it repeatedly with a dilute solution of hydrochloric acid (5 parts of strong acid to 95 parts of water). Before using the acid, the object should be thoroughly wet in order to minimize the amount of acid penetrating the pottery. Calcium sulphate generally falls off during soaking in water to dissolve out salt, or softens sufficiently to be readily detached, but may be removed by treatment with hydrochloric acid in the same way as for carbonate. After acid, the object must be washed in repeated changes of water until no trace of the acid remains. Baking will cause calcium sulphate to crumble to powder and fall off, but frequently the object is too large for baking to be conveniently applied.

The exceptions to the above-mentioned methods of treatment are objects that have been painted after having been fired. Although these may sometimes be soaked in water without damage,

if the soaking is not too prolonged, the safest way of removing salt from painted pottery in cases in which it is unglazed and when the paint has not been burnt in, is to clean the surface as far as possible with petroleum spirit (benzine, petrol) or alcohol [1] and a small soft brush, avoiding rubbing, dry thoroughly and treat with several coats (usually about four) of a dilute (1 per cent.) solution of celluloid and then soak the object in repeated changes of water until all the salt is dissolved out. After thorough drying, the celluloid treatment should be repeated.

Acid should never be employed for removing incrustations from painted pottery until it has been proved by an experiment on one small portion that it will not affect the pigment.

Sometimes early pottery that has not been well baked may become very friable and rotten from lying in damp ground. In such cases the object should be dried slowly, but thoroughly, and then impregnated with hot melted paraffin wax, preferably by immersion in the wax, but if this is difficult or impossible, then by painting it inside and out with very hot wax and afterwards gently heating it in a warm (not hot) oven, or before a fire or electric radiator until all the wax on the surface sinks well in. Repeated treatment with

[1] See footnote [1], p. 20.

dilute celluloid solution will also consolidate such pottery, but usually wax is preferable.

Ostraca

In this connexion fragments of pottery bearing written inscriptions may be mentioned. That an ink inscription on pottery (also on wood or stone) becomes more visible when wet is well known and therefore inscriptions are often wetted in order that they may more easily be deciphered or photographed. This is most unwise and is very liable to destroy the writing, as the carbon ink used for the writing readily rubs off when wet. A perfectly safe method of bringing up such inscriptions is to pour on them a small quantity of petroleum spirit (benzine, petrol) or alcohol. The effect, as with water, is only temporary, but it may be repeated as often as required without danger to the writing.

The best manner in which to treat ostraca is first to brush off any superficial dust with a soft brush, then to clean them with petroleum spirit or alcohol and a small soft brush, avoiding rubbing, and when dry to coat the inscribed portions repeatedly with a dilute (1 per cent.) solution of celluloid. If salt is present, this may be dissolved out without any danger to the inscription, by soaking in water after the celluloid treatment and, when free from salt and thoroughly dry, the celluloid treatment should be repeated. Mastic varnish,

as used by artists, sometimes brings out an inscription better than celluloid, but it is very unsightly, and celluloid, which is generally quite satisfactory, is recommended, especially if the ostraca are to be exhibited.

Pottery may be repaired with celluloid cement, glue or plaster of Paris, and missing portions may be replaced by tinted plaster, which when thoroughly dry may be treated with hot melted paraffin wax as already described.

Stone

The cleaning and preservation of stone may be considered under two heads, namely, first, building stone; and second, stone used for purposes other than building, for example, for sarcophagi, stelæ, statues, statuettes, ornamental carving, bowls and vases.

The two principal varieties of stone employed for building at all periods have been limestone and sandstone, and in ancient buildings these stones necessarily have been exposed to atmospheric influences for many years and a certain amount of damage which usually cannot be prevented has been produced by variations of temperature, the mechanical action of wind-borne sand, the solvent action of water (rain), and other causes. In addition to these destructive agents there are two others that

are the most potent of all, one operative in large towns in manufacturing districts and the other limited to countries like Egypt, where rain is almost entirely absent. The agent in the former case is sulphuric acid, derived from the combustion of coal and coal gas, and in the latter case is salt, which gains access to the stone from salty subsoil water or from salty ground.

The problem of the cleaning and preservation of building stone exposed to sulphuric acid has been engaging the attention of experts for many years, and a large amount of scientific research on the subject has been, and still is being, carried out. Up to the present no satisfactory solution of the preservation part of the problem has been found, but it is generally admitted that treatment with the so-called "stone preservative solutions," though occasionally of value for a short time, is often useless and may even be harmful. The cleaning of the stone, however, is fairly simple, and dirt and soot may safely be removed either with a powerful jet of water or by means of steam. Caustic alkalies (potash and soda) should not on any account be employed, as their use is inevitably followed by efflorescence and decay.

The problem of freeing building stones from salt is necessarily limited to hot, dry countries, as it would be impossible for salt to accumulate

in a climate where there is much rain. When once the walls of a building have become impregnated with salt, it is ordinarily impossible to remove it, though this has once been done quite unintentionally, in Egypt. The phenomenon occurred at Philæ, near Aswan, where the temples and other buildings became infected with salt, derived from the soil of the island, when the level of the river up-stream of the Aswan dam was first artificially raised by the closing of the sluices. This salt has since largely been washed out again from the stone during the annual submergence and now only remains in small amount in those parts that are just above the highest water-level and it will disappear altogether when the work of the heightening of the dam, now in progress, is finished and the water-level still further raised, as this will entirely submerge, for several months annually, all the buildings on the island.

Although, when once a building becomes saturated with salt, this as a rule cannot be removed, yet much may be done to improve the condition of affairs and to avert absolute disaster. Thus the access of fresh salt may usually be prevented, the amount in the stone may be diminished and that left may be so dealt with that it no longer causes damage.

If the salt is derived from salty subsoil water, the level of this may be lowered by suitable drainage to such an extent that it can no longer act as a feeder of salt to the stone. If the level of the subsoil water is satisfactory, and if the drainage conditions are good, the salt-impregnated ground may be thoroughly and repeatedly washed with fresh water, or, if the drainage is poor, the soil immediately around the building, to a distance of about a metre (yard) from the walls and to as great a depth as is safe for the foundations, may be removed and replaced with fresh salt-free earth or sand.

The amount of salt in the stone near the ground-level, where it is always present to the greatest extent, and where as a rule there is no inscription, paint or sculpture, may often be lessened by careful brushing and scraping, followed by the application of damp cloths, damp sand or damp paper pulp. The quantity of water used must be very small, otherwise it will penetrate to the adjoining painted, inscribed or sculptured area and will cause injury.

The method of bottling up salt so as to prevent its doing damage has already been described.[1]

The treatment of stone, other than building stone, depends upon the nature of the stone, the

[1] See p. 146.

condition of the object and the cause of the disfigurement or damage.

The stones employed in antiquity were of many different kinds, but the principal ones and the only ones that need be considered were alabaster, limestone, marble, sandstone, granite and the very hard rocks, such as basalt, diorite, dolerite, porphyritic rock, and schist, which latter may be dealt with first.

Hard Stone

The very hard stones, being only very slightly permeable to water, are usually free from salt (which can only gain entrance in water solution) and, unlike limestone, sandstone, and granite, they were not painted. These stones, therefore, are readily cleaned and, beyond cleaning, usually no further treatment is needed. These hard stones may be freed from dirt and mud by simple washing with soap and water and a stiff bristle brush, followed by copious rinsing with clean water. In rare cases on large statues there may be patches of mud cemented to the stone with calcium carbonate (carbonate of lime) or less frequently with calcium sulphate (sulphate of lime) or there may be hard concretions of the carbonate or sulphate, derived from burial in damp sand or earth containing these substances. The calcium carbonate is best removed by painting it over repeatedly with a dilute solution of acetic acid

(equal parts of strong acid and water), the material as it softens being brushed off with a stiff bristle brush or taken off by means of a chisel-shaped piece of hard wood,[1] the object being finally repeatedly well washed with water. Unfortunately calcium sulphate cannot be removed with acetic acid and for this hydrochloric acid must be used (20 parts of strong acid to 80 parts of water), but it must be used sparingly and the object must be thoroughly washed afterwards until it is free from all traces of the acid. This washing is difficult with objects that are too large to soak, but thorough washing, preferably with a hose, is essential, as hydrochloric acid is much more dangerous than acetic acid if allowed to remain.

Alabaster

The name alabaster is applied to two entirely different materials, one being hydrated calcium sulphate (sulphate of lime) and the other calcium carbonate (carbonate of lime), which are very similar to one another in appearance. In England and in Europe generally, alabaster usually means the sulphate, which is a fine-grained, compact, massive variety of gypsum used for making vases, ornaments and other objects. In Egypt, on the other hand, alabaster always means calcium carbonate, and it is this material that was employed

[1] Iron or other metal should not be used, as it may scratch the stone.

for sarcophagi, statues, statuettes, vases, bowls, and other objects. Geologically the material is calcite, though sometimes it is erroneously termed aragonite, a material of similar composition, but different crystalline form and different specific gravity. The massive form of calcium sulphate (gypsum) occurs in several localities in Egypt, and it was very occasionally employed for carving into small objects, such as vases, but this should not be called alabaster, but gypsum.

The first step in the cleaning of alabaster is careful washing with soap and warm water, aided if necessary by the use of a brush not hard enough to scratch the surface. All ordinary dirt and even the most unpromising-looking stains may be removed in this manner. After washing, the object should be well rinsed in clean water and placed on a clean cloth to drain and dry. When simple washing is not effective prolonged soaking in water should be tried, a drawback to this, however, being that it will probably remove all the polish from the stone.

If there are stains that water will not remove, petroleum spirit (benzine, petrol), alcohol,[1] acetone, benzol and pyridine should be tried in the order named, that particular reagent being used that gives the best results.

[1] See footnote [1], p. 20.

If the object is a vase it may contain organic matter that, unless removed, may detract very much from the appearance, as the walls of vases are frequently sufficiently thin and translucent for a dark material to show through. As much of the contents as possible should be scraped out with a piece of wood and, unless the material is definitely of a fatty nature, the vessel should be filled with warm (not hot) water and left to soak, and afterwards washed out repeatedly with warm water. A piece of cloth tied to the end of a stick, or a brush such as is used in chemical laboratories for cleaning bottles, will be found useful.

If the contents of a vase are of a fatty nature, or if water will not remove them, petroleum spirit (benzine, petrol), alcohol, acetone and benzol should be tried in the order named, the one that gives the best results being chosen. For these reagents to be effective the material must be thoroughly dry, and therefore, if water has been used, this must be removed, and the best and quickest way of doing this is to rinse several times with alcohol, which takes up the water, drain and place in a warm place to dry, alcohol drying much quicker than water. Petroleum spirit is satisfactory for fatty matter, alcohol for resinous matter, and acetone, benzol and pyridine for many miscellaneous materials of an organic

nature. Considerable time and patience are frequently required to clean the inside of a vase.

Acids must never be employed to clean alabaster, as they act upon and dissolve it.

Occasionally, round the top of an alabaster vase, there may be the remains of cementing material used to fasten on a lid. This is frequently beeswax or resin, and it is generally brittle and the greater part may readily be removed with a penknife. It should not be forgotten, however, that alabaster is a fairly soft material, and is easily cut or scratched, and when it has been in contact with organic matter of an acid nature, such as decomposed fatty matter, it becomes very soft and friable. The use of a knife, therefore, is dangerous and no attempt should be made to remove the last traces of the cementing material in this way, as it is almost impossible to do so without damage, the final stages of the cleaning being done by means of a solvent, such as turpentine for beeswax and alcohol for resin. Other reagents, among which are acetone, petroleum spirit and hot alcohol, will also soften beeswax but will not dissolve it, and might be used when turpentine is not obtainable. The liquid is applied with a rag or brush, and the cement when softened may be scraped off with a piece of bone or wood, such as a small paper-knife.

Gypsum objects may be cleaned in the same manner as alabaster (calcite), but it should be remembered that gypsum is softer than calcite and therefore is more easily scratched; gypsum is also more susceptible to the action of water than calcite, and therefore more easily loses its polish.

Alabaster and gypsum may be repaired with celluloid cement in the case of small articles and with plaster of Paris for large objects. Missing parts may be replaced with plaster of Paris, which when dry may be treated with celluloid or with paraffin wax as already described.

Limestone

Limestone was the stone most commonly used in ancient Egypt for inscriptions, low relief sculpture, painting and statuettes, partly on account of its abundance, but also because it is easily worked and has a smooth surface and a good appearance.

On account of its porous nature, limestone is very liable to contain salt, and the author has found as much as 4·6 per cent. in a specimen taken direct from the quarry. Usually, however, any salt present has been derived from salty ground. This salt always consists essentially of sodium chloride (common salt), but sometimes contains sodium sulphate and occasionally small proportions of other salts, such as sodium carbonate, sodium nitrate, and potassium nitrate.

Salt is one of the most destructive agents to stone known: its action is not chemical and therefore not analogous to its action on metal, but entirely physical; and is caused by the salt, which is brought to the surface by capillary attraction when the stone dries, crystallizing underneath the surface layers, which are forced off by the irresistible expansion of the growth of the crystals, and thus any inscription or painting is destroyed. When a stone is quite dry, salt is harmless, but it is impossible to keep a salty stone dry, as salt absorbs water even from a damp atmosphere.

As the salts causing the mischief are soluble in water, the obvious way of removing them would seem to be to soak the stone in water until it is free from salt. In many cases, however, this cannot be done, either because the object is too large, or on account of the presence of plaster on the surface and in other cases it is only possible to do it without damage if certain precautions are taken. In those instances in which soaking is possible and permissible, the object should be entirely immersed in water contained in a stone or cement basin or in a wooden box lined with lead or zinc (but not in iron or tinned iron). The object should be raised above the bottom of the vessel on brick or stone supports, but not on metal, as metals such as iron or copper would

discolour the stone. The water must be changed frequently, until on testing it is found to be free from more than a trace of salt. This will take many weeks and often months. The stone when removed from the water should be allowed to dry slowly in a warm place and for the first few days it should be loosely covered with a light cloth in order to prevent too rapid evaporation, which sometimes disintegrates the surface. This precaution is one that should be taken when drying any stone, not only those that have been soaked intentionally, but also those found in wet ground. In this connexion it should not be forgotten that water has a slight solvent action on limestone and with prolonged soaking, especially in running water, the sharp outlines of carvings and inscriptions may suffer. The growth of algæ, which tend to develop, especially in warm weather, may be prevented by frequent changing of the water and by covering the vessel so as to exclude the light.

Sometimes crystals of calcium sulphate occur on limestone objects that have lain in damp ground containing gypsum. Any such crystals will either fall off during the soaking or will so soften that they may readily be detached by a hard brush or a piece of wood. Metal should not be used as it will mark the stone, and even wood must be used with care, as some limestone is very

soft and easily scratched. Acids also must not be used on limestone, as they act vigorously upon it and dissolve it.

Limestone objects that bear painted inscriptions or scenes must not on any account be wetted until the painted surface has been protected from the action of water, or the paint will be destroyed. The necessary protection may be given by repeatedly treating the surface of the stone with a dilute solution (1 per cent.) of celluloid, generally four to six coatings being required. Painted limestone objects thus protected have been soaked in water for many months without any loss of paint. After drying, one or two further coats of celluloid solution should be given.

Preservatives of unknown composition should never be employed, and all substances such as sodium silicate (water glass), potassium silicate, silico-fluorides (fluosilicates, fluates) and baryta should be avoided, partly because they can only be used in aqueous solution, which is most undesirable if the stone is salty, but also because they generally form a thin skin on the surface of the stone that eventually scales off, bringing some of the stone with it, while as a secondary effect they often cause an efflorescence of salt which increases any distintegration taking place. Paraffin wax also should not as a rule be employed, as it

darkens, not only the stone, but also any pigments present.

Occasionally limestone naturally contains veinlets of common salt or is so largely impregnated with salt that it is barely holding together. In such cases, washing with water would be fatal and the only remedy is to treat the stone with celluloid solution without attempting to remove the salt. When the disintegration is less pronounced the object may be wrapped tightly in gauze before being soaked.

Sometimes objects bearing painted inscriptions may have a layer of plaster under the paint, or irregularities in the stone may have been corrected with plaster. Such objects cannot be wetted without the plaster coming off, and if salty they must be treated with celluloid solution without any attempt being made to remove the salt.

The method of cleaning painted limestone has already been given in connexion with mural paintings. As a rule the paint does not require consolidation unless salt is present, but if necessary it may be treated repeatedly with a dilute solution (1 per cent.) of celluloid, and repairs are best carried out with celluloid cement. Certain black spots (dendritic markings) that are occasionally found disfiguring limestone (and sandstone) are due to oxides of manganese or mixed oxides of

iron and manganese, natural to the stone and cannot be removed.

As alternatives to soaking the repeated application of (*a*) damp sand [1] and (*b*) wet paper pulp [2] have been proposed and each of these methods, especially the latter, may be most useful on occasions, but for routine work when a large number of objects require treatment at the same time, the author has found soaking to be the best; also paper pulp becomes expensive when used on a large scale; the application of paper pulp, too, although simple in the case of flat objects, is not easy with objects that have ornamentation or undercut parts and is not always safe with painted objects. A drawback of soaking is that it takes a long time, always days, often weeks and sometimes months, but when properly carried out it is very efficient and it has two great advantages, namely, first, that a large number of objects may be treated simultaneously, and second, that it requires very little skilled attention.

Marble Marble may be cleaned with soap and water and a fairly stiff brush, and if salty, as sometimes happens, for example with gravestones in Egypt, it should be soaked, if the condition will allow,

[1] W. M. Flinders Petrie, *Ancient Egypt*, 1925, pp. 21–2.

[2] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, Third Report, 1926, pp. 14–21.

until free from salt. To remove oil or grease from marble is not easy, but sometimes the amount may be reduced by treatment with petroleum spirit (benzine, petrol) or by leaving on the stained portion a pad of cotton-wool or other material kept wet with petroleum spirit, ammonia or pyridine. Fuller's earth is often recommended for this purpose, but the author has not found it of much value for old stains. Scott has recently removed red ink from a marble bust with chloramine-T, and tarry smoke from another bust by means of an emulsion of benzol, dilute aqueous ammonia, and a little methylated spirit.[1]

Sandstone

Sandstone may be treated in the same manner as limestone. It is sometimes very deceptive in appearance and not nearly so strong as it appears, but often very friable and fragile, requiring great care in handling. If sandstone is soaked in water to remove salt, it should not be forgotten that when wet it becomes still more fragile. After soaking, it should be dried very slowly, the upper surface being lightly covered to prevent too rapid drying. Sandstone may be consolidated and any paint present fixed by treatment with dilute celluloid solution, while for repairs celluloid cement will be found satisfactory.

[1] Dr. Alexander Scott, "Romance of Museum Restoration," *Journ. Royal Society of Arts*, LXXX (1932), p. 494.

Granite Granite, although naturally a hard rock, often suffers considerable surface disintegration both from weathering and from salt. Granite may be repaired with plaster of Paris or with celluloid cement and any paint may be fixed by treatment with celluloid solution. Salt, if present, may be removed by prolonged soaking in water.

In the case of small objects that can be soaked conveniently in water after treatment to remove all trace of the reagent, hard incrustations of calcium carbonate may be removed by brushing them over with a dilute solution of hydrochloric acid, but if the object is too large for soaking, acetic acid should be employed instead.[1]

General Stone that contains, or that may contain salt, should never be embedded in plaster or cement, nor should it be fixed in a wall by means of plaster or cement, but should be framed in wood, as the water necessarily used with the plaster or cement will inevitably penetrate the stone and dissolve part of the salt, which will be brought to the surface when the stone dries, thus causing considerable disfigurement or damage. Petrie states [2] that " Sculptures have been entirely wrecked by being cemented into the wall of a museum," and

[1] See pp. 196–7.

[2] W. M. Flinders Petrie, *Methods and Aims in Archæology*, 1904, p. 86.

the author has seen many examples of injury caused in this manner. In one instance a poor quality of plaster of Paris containing salt was employed and salt was thus imported into stone that previously did not contain it.

In cases where metal clamps or dowels are employed for repairing stone, these should preferably be of copper or bronze and not of iron.

Wood

Wood is subject to many ills, including the attacks of insects and fungi, the action of water-soluble salts and staining by oil. These will now be considered.

Insects

The principal insects that destroy dead wood (excluding marine woodboring molluscs and crustaceans) are white ants (termites) and the larvæ of several kinds of beetle.

The white ant is sometimes found infecting ancient tombs, as in certain parts of Egypt, and in such cases there is no remedy, since the mischief will already have been done before the tomb or other excavation is opened, and wooden objects, unless they are made of a few certain kinds of wood which seem to be largely immune, will already have been destroyed when found. Museums, too, are occasionally invaded by white ants. When there is any danger of this the enemy may be

kept out by the following mentioned precautions, namely, (*a*) clear spaces covered with sand, gravel, stone, brick or asphalt surrounding the building; (*b*) all woodwork to be insulated from the ground by at least a foot of stone, burned brick or concrete; (*c*) floors to be of stone, cement or tiles and not of wood; (*d*) show-cases and wooden objects resting on the floor to be protected by metal sheeting underneath. Other remedies, such as tar, creosote and paint, also protect wood against white ants, but they cannot be applied to antique objects on account of the disfigurement caused.

Boring beetles may be kept out of wooden objects by well-fitting show-cases, though even the cases, if of wood, may be attacked. When an object is infected, the best remedy for ordinary application to small objects is fumigation with carbon disulphide or with a mixture of ethylene dichloride and carbon tetrachloride. which may be done in the show-case by leaving some of the liquid exposed for several days, so that it will evaporate and saturate the air and also the contents of the case. Carbon disulphide being very inflammable, special precautions must be taken against fire.[1] Other methods that may be employed are injecting the wood with turpentine containing 5 to 10 per cent. of paraffin oil (kerosene)

[1] See p. 50.

or with turpentine alone, the addition of paraffin oil, however, being preferable, as it causes the liquid to spread better. The liquid is injected into all the holes [1] with a syringe or by means of a small oil-can having a long nozzle.[2] After treatment, the holes should be stopped up with beeswax, or with beeswax (3 parts) and powdered rosin (1 part), or with paraffin wax suitably coloured. As some of the larvæ or eggs may escape the first application, the injection should be repeated should any fresh holes or other signs of the beetles or larvæ appear.

Fungi

The well-known decay of wood called "Dry Rot" is caused by several kinds of fungi. The term, however, is a misnomer, the decay not being due to the wood being dry, as moisture must be present before the fungi can grow, but to the dry powdery appearance of the wood when badly attacked. The conditions most favourable to the production of dry rot are a warm, moist and stagnant atmosphere, and the best prevention is good ventilation.

Salts

It is not usual to find salts in wooden objects, though they occur occasionally, being generally

[1] Although the holes are exit holes of the mature beetle, they communicate with the infected area and provide a way of reaching larvæ and eggs still in the wood.

[2] The kind of oil-can that needs pressing at the bottom to eject the oil.

derived from the ground in which the objects have been buried. When salt is present it is chiefly in the form of common salt, though a case is recorded [1] in which wooden objects were impregnated with ammonium compounds derived from guano and the author has dealt with ancient Egyptian wooden objects that were saturated with natron. Although with wood the use of water should if possible be avoided, there are instances, such as those mentioned, when the only remedy is to soak the object in water or in a water solution; for example, in order to remove the ammonium salts dilute acetic acid was employed, followed by washing in water.[1] After having been wetted, the objects must be carefully, and above all slowly, dried, this last being essential, or the wood may warp. Soaking in alcohol after water helps drying.

Consolidation

When dry, it is often useful to impregnate the wood with melted paraffin wax, which is one of the most valuable remedies for the treatment of wooden objects in a poor state of preservation. If possible the object should be warmed before applying the wax, which should be very hot, and if the treatment is carried out carefully, the wax all soaks in without leaving any excess on the

[1] Dr. Alexander Scott, *The Cleaning and Restoration of Museum Exhibits*, Second Report, 1923, pp. 8–9.

surface to cause disfigurement. Should any surplus wax be left, this may be wiped off while hot with a soft cloth or removed by heat.[1] Wax, however, has one great drawback, namely, that it darkens the wood and, if the wood is painted and not varnished, the darkening shows through the paint and spoils the appearance of the object. Wax may also directly darken the pigments, some colours being more affected than others. On a painted and varnished surface wax has no darkening effect, but with varnish, especially the black varnish that often occurs on ancient Egyptian funerary objects, care should be taken that the wax is not too hot or the varnish may be blistered.

An alternative to wax is treatment with dilute celluloid solution, which consolidates the wood in a very satisfactory manner, though even celluloid may slightly darken some kinds of wood.

Oil Stains

Oil or grease may be removed from wood by soaking it in benzol or in petroleum spirit (benzine, petrol) or in acetone, or, if this is not possible, the stains should be treated with any of these reagents applied with a soft cloth.

Inscriptions

Inscriptions written with carbon ink on wood may be rendered temporarily more legible for decipherment or photography by carefully pouring over them petroleum spirit, or alcohol, or by im-

[1] See p. 37.

mersing the objects in these reagents. Water, which is sometimes used for this purpose, is most unsatisfactory, as it is likely to remove some of the ink.

Unpainted Objects

Unpainted objects, if the wood is hard and in good condition, may be cleaned with a damp sponge or damp cloth.

Painted Objects

Painted wooden objects, if varnished, may be cleaned with a damp sponge or damp cloth, but, if unvarnished, water should not on any account be used, as it removes the paint, and such objects, after preliminary dusting with a soft brush, should be cleaned by means of petroleum spirit (benzine, petrol) and a soft brush, even alcohol affecting the paint slightly. After cleaning, the paint may be fixed by repeated treatment with dilute celluloid solution.

Repairs

The usual adhesive for repairing wood is glue, which as a rule is very satisfactory, but occasionally celluloid cement is a useful substitute. For stopping cracks and holes in wood, or for filling up spaces where parts of the wood are missing, an excellent material may be made from celluloid cement and fine sifted sawdust.[1] Before using the stopping, the edges of the holes should be treated with several coats of dilute celluloid solu-

[1] A preparation of this nature called "Plastic Wood" is now on the market.

tion. When dry, the stopping may be stained to match the colour of the wood, a good brown stain being a solution of potassium permanganate in acetone.

Woven Fabrics

Ancient woven fabrics vary very much in their state of preservation, some being in excellent condition and others being badly decayed and falling to powder. The reason for the disintegration is not fully understood, but the factors that appear to be of importance are air, warmth and humidity, and it seems probable that the changes are partly chemical and partly biological, the chemical action being in the nature of oxidation and the biological effects being brought about by bacteria and fungi (moulds). Sunlight, too, produces disintegration of fabrics, but cannot be one of the causes when the fabrics have been shut up in a tomb.

Fabrics such as rugs, tapestries and mounted pieces, may be cleaned from loose dust and dirt by means of a vacuum cleaner, but this can only safely be used when the fabric is in good condition and even then a small machine with only a weak suction should be employed, or the fabric may be damaged.

Dirt, other than loose dust, may often be removed from certain kinds of fabrics such as lace,

that are in a good state of preservation by means of soap and warm water without rubbing, as follows. The fabric is immersed in cold water and a small amount of soap solution, made from a good quality pure white soap, added. The whole is then slowly heated, almost to boiling, and left for some time, after which the fabric is taken out and transferred to a bowl of clean warm water, this time without soap, and gently and carefully moved about. This treatment is repeated with fresh water. The fabric is then removed from the water, put on a clean white cloth and allowed to drain and finally straightened out and placed between white cloth or white blotting-paper, pressed gently and allowed to dry slowly. When handling a wet fabric it should not be forgotten that the water makes it heavier and therefore more liable to tear than when dry. Merely ironing a fabric, with or without slight damping, will often considerably improve and strengthen it.

White cotton or linen fabrics that have become discoloured may be bleached in the same manner as prints,[1] namely, (*a*) by being placed in water and exposed to the sun for several hours; (*b*) by hydrogen peroxide, which is expensive; or (*c*) by means of bleaching powder or of sodium hypochlorite, which, however, cannot be used for wool

[1] See pp. 173–6.

or silk. The fabric should not be folded during treatment, and it must be entirely immersed in the water or other solution.

When fabrics are in a good state of preservation, but contain salt, as may happen in wrappings or garments on bodies that have been treated either with natron (which always contains salt) or with salt, and which often occurs in the case of Coptic garments on account of their frequent burial in damp and salty soil, the salt may be removed by soaking in repeated changes of pure water, but this treatment cannot be applied to fabrics that are in poor condition.

The simplest way of removing oil or grease stains from fabrics is to soak them in petroleum spirit (benzine, petrol). Occasionally, however, the stain may be very persistent and may not be removed, or not easily removed, by this treatment, and in such a case, acetone should be tried, since animal and vegetable oils (not mineral oils) are more easily soluble in the latter than in the former. If the fabric cannot be immersed, the solvent should be applied to the stain by means of a soft cloth or a pad of cotton-wool, and the stain should be prevented from spreading by "ringing" it, that is, by moistening the material round the spot with water, or with a mixture of equal parts of alcohol and water.

The method of removing ink stains varies with the nature of the ink. Carbon ink (Indian ink, drawing ink) may be removed with warm water and gentle rubbing. Old iron ink, without any provisional blue colouring matter, may be removed by means of hydrogen peroxide, which is expensive, or with a dilute solution of oxalic acid (10 per cent.), allowing it to remain on the stain for a few minutes, washing it off and if necessary repeating the application of the acid and finally thoroughly washing with warm water. Stains made with a modern blue-black ink, which is an iron ink containing a blue colouring matter, generally an aniline dye, may be removed by applying alternately oxalic acid (10 per cent.) or tartaric acid (10 per cent.) and a dilute solution of bleaching powder (1 per cent.) or of sodium hypochlorite (0·5 per cent.) and finally washing well with warm water.

Iron stains (iron mould) are best removed by dabbing them with a solution of oxalic acid (10 per cent.) and afterwards well washing with warm water, which latter is essential, since the acid, if left on, makes the fabric tender.

Tapestry should be backed with another fabric, preferably linen, which should have a fine close texture in order to keep out dust. Fabrics in a fragile condition should also be backed, the nature

of the backing depending upon the nature and state of the fabric.

As fabrics, particularly woollen articles, are very liable to the attacks of insects, they should be kept in well-fitting cases, in which naphthalene, thymol or paradichlorbenzene is exposed, none of which, however, confers more than a limited protection against certain kinds of insects. To prevent mildew, damp should be excluded. When fabrics are attacked by insects, fumigation with carbon disulphide, or with ethylene dichloride and carbon tetrachloride is the only remedy. The method of fumigation has already been described.[1]

A very large number of experiments have been made in order to determine, if possible, the most satisfactory manner of strengthening fragile and disintegrating woven fabrics, and it was found that a dilute solution of celluloid (1 per cent.) dissolved in acetone gave the best results and that a similar dilute solution of cellulose acetate, also in acetone, gave the next best results. Since cellulose acetate is a more stable compound than celluloid, which eventually may develop slight acidity on keeping, and since old fabrics are particularly susceptible to traces of acid, the use of cellulose acetate is recommended.

When a fabric is found in a wet condition, or

[1] See p. 50.

has been accidently wetted, it should be dried slowly in a warm room and not by direct exposure to a fire or other source of heat.

Ancient fabrics are sometimes in such a dry and tender condition that they cannot be unfolded without considerable damage, and often they are so fragile that damping with water or steaming would destroy them. Occasionally in such cases damping the fabric with benzine (petrol) or alcohol will enable them to be handled in safety.

CHAPTER IV

SIMPLE PHYSICAL AND CHEMICAL TESTS

Detailed physical examination or chemical testing are matters for the specialist, but the knowledge of how to carry out certain simple tests will be advantageous alike to the archæologist, the curator and the collector, and a few such tests therefore may be described. The physical tests should be done before the chemical ones, as generally the amount of material available for testing is very small and the chemical tests destroy the portion tested, whereas the physical tests do not. The materials mentioned are those likely to occur in connexion with antique objects.

Physical Tests

The useful tests are as follows:

1. Examination with a lens.
2. Determination of hardness.
3. Nature of fracture.

These will now be considered in detail.

Examination with a Lens

From the examination of a material with a lens much may be learned, and details of colour, structure and composition not visible to the naked eye may be seen. Specimens of known and likely materials should be examined alongside the doubtful material. A good hand lens having a magnification of at least 10 diameters, is recommended.

Hardness

Hardness is a most useful test for the identity of mineral substances. It may be determined in several different ways: first, by scratching the material with the thumb-nail; second, by scratching it with the blade of a steel penknife; third, by rubbing the material on a small, fine, clean, hard file and noting the extent to which it is affected; and fourth, by scratching the material with various minerals of known hardness.

The hardness of a mineral is expressed by a number. The following tabular statement shows the hardness of the principal materials likely to occur. The thumb-nail will scratch minerals of a hardness not exceeding 2·5, and a penknife will scratch minerals up to a hardness of about 5·5, thus gypsum may be easily scratched with the nail, whereas alabaster (calcite) requires a knife to scratch it, and quartz cannot be scratched even with a knife, which means that it is harder than steel. The minerals with a hardness of 6 will just scratch ordinary window glass, while those with

a hardness of 7 or upwards scratch glass easily. When a mineral neither scratches nor is scratched by a particular substance, the hardness of the two is about the same. After making a scratch the powder should be wiped off and the surface examined with a lens in order to make sure that the powder does not come from the scratching agent, which may happen when the two substances are of nearly the same hardness.

TABLE OF HARDNESS

Number	*Material*
1	Steatite.
1·5 to 2	Gypsum.
3	Alabaster (calcite).
3 to 4	Serpentine.
3·5 to 4	Malachite.
5·5	Glass, lapis lazuli, obsidian.
5·5 to 6·5	Hæmatite.
6	Felspar, hæmatite, turquoise.
6 to 7	Peridot.
6·5	Jade.
6·5 to 7	Jadeite.
6·5 to 7·5	Garnet.
7	Agate, amethyst, carnelian, chalcedony, flint, jasper, quartz, rock crystal.
7·5 to 8	Aquamarine, beryl, emerald.
8	Topaz.
9	Sapphire.
10	Diamond.

Fracture

The nature of the fracture produced when minerals and other materials are broken is often

very characteristic. The different kinds of fracture are as follows:

1. *Conchoidal.*—When the broken surface is curved, either convex or concave. Examples: Amber and many other resins, flint, glass, obsidian, quartz.

2. *Even.*—When the surface is flat or nearly so. Example: Chert.

3. *Earthy.*—Example: Chalk.

Chemical Tests

The apparatus required for the chemical tests consists of a few small test-tubes and watch glasses; a small piece of thin platinum wire, thin iron wire or nickel-chrome wire, and blue and red litmus paper.

The tests are:

1. Solubility.
2. Behaviour on heating.
3. Reaction with acid.
4. Testing of solutions formed when the material is soluble in water or acid.
5. Flame coloration.

These may now be described. Before undertaking any chemical tests it should be seen that all reagents are pure and all apparatus thoroughly clean.

Solubility

For solubility a small quantity of the material is powdered finely and tested to see whether it is soluble, (*a*) in water (distilled if possible), (*b*) in alcohol, and (*c*) in petroleum spirit. This may be done on a watch glass or in a small test-tube.

Soluble in Water.—Sodium carbonate; sodium nitrate; sodium sulphate; potassium nitrate (saltpetre); salt (common salt, rock salt). Glue and gum are first softened by water and then dissolved. Clay disintegrates in water and feels soapy.

Soluble[1] *in Alcohol.*—Resin, resin varnish, wood pitch.

Soluble[1] *in Petroleum Spirit (benzine, petrol).*—Bitumen,[2] mineral pitch,[2] fat, grease, oils.

Behaviour on Heating

To apply the heating test place a small piece of the material on the point of a penknife and heat in the flame of a gas jet, spirit lamp or candle. Note (*a*) whether the material melts, (*b*) whether it burns, and if so whether freely or not, (*c*) the smell produced, and (*d*) the nature of the residue, if any. If the material melts before it burns it is possibly fat, resin or wax (beeswax). Smear it while melted on a piece of white paper. A translucent stain indicates either fat or wax. If the material burns it is most probably organic although

[1] Or largely soluble.

[2] The solution is generally fluorescent.

it should not be forgotten that some inorganic substances, sulphur for example, also burn. Other inorganic materials, such as ammonium chloride, disappear when heated by volatilization and not by burning. The smell of the burning material is often very characteristic, and bitumen, mineral pitch, fats, oils, resin, sulphur and nitrogenous matters (hair, horn, mummy flesh) may all be identified by the smell.

Reaction with Acid

To test the reaction with acid, take a few small fragments or scrapings if the object is one that may be cut or scraped, powder them finely, and place a little of the powder in a small test-tube or on a watch glass and pour on it a little dilute hydrochloric acid and note the result. If the object may not be cut or scraped, place on it in an inconspicuous place (by means of a small pipette or a fine glass rod) a small drop of dilute hydrochloric acid and watch the result with a lens.

The following mentioned are soluble with effervescence, namely the various forms of calcium carbonate (alabaster (calcite), chalk, coral, limestone, marble, whiting); also malachite (which forms a green solution).

The following named is soluble slowly without effervescence, especially on heating, calcium sulphate (gypsum).

Testing of Solutions

Water Solution.—The solution formed by dissolving any material in water should be tested as follows:

1. For alkalinity and acidity, which may be done by means of litmus paper. If the solution is alkaline, red litmus turns blue, whereas if the solution is acid, blue litmus becomes red.

Another test for alkalinity is to add a few drops of a 1 per cent. solution of phenolphthalein in alcohol,[1] which produces a red colour in the presence of alkali. This is the best reagent to use in order to ascertain whether all the alkali has been washed out of a metal object that has been cleaned, or finished off, in an alkaline solution. It should not be forgotten, however, that both glass and enamelled iron vessels often yield small amounts of alkali to water and therefore a persistent trace of red colour in the water in which an object has been washed may be due to this and may be disregarded.

2. For the presence of chloride, which will generally indicate common salt or natron (which contains salt).

Chloride is tested for by means of silver nitrate. To a little of the solution contained in a test-tube or in a watch glass add a few drops of a 10 per

[1] Test papers impregnated with phenolphthalein, which are often more convenient than a solution, may be bought.

cent. solution of silver nitrate. A milkiness indicates a trace of chloride, and a curdy precipitate means a larger amount. This should be confirmed by adding a few drops of dilute nitric acid (10 parts of strong acid to 90 parts of water) which should not produce any change, that is to say, the milkiness or precipitate should not disappear. A white precipitate soluble in nitric acid generally indicates sodium carbonate or natron. Ordinary pure water contains a trace of chloride, and well water often contains a considerable amount, which, therefore, must be allowed for, and whenever possible distilled water should be used. This is the test employed to ascertain whether all the salt has been washed out of pottery, stone and other objects, and to ascertain also whether all the hydrochloric acid has been removed from objects that have been treated with this reagent.

3. For the presence of sulphate, which will generally indicate sodium sulphate, but may mean magnesium sulphate.

Sulphate is tested for by means of barium chloride. To a little of the water solution contained in a small test-tube or in a watch glass add a few drops of a 10 per cent. solution of barium chloride. A slight cloudiness appearing after a time indicates a trace of sulphate, an immediate heavy white precipitate indicating a larger amount.

This should be confirmed by adding a few drops of dilute hydrochloric acid, which should not dissolve the precipitate. Care should be taken not to make the solution too acid, otherwise the hydrochloric acid will produce a precipitate, which, however, disappears on diluting with water.

Acid Solution.—This should be tested for sulphate in the same manner as described for the water solution. A precipitate with barium chloride indicates sulphate, which, in the absence of sulphate in the water solution, will generally mean calcium sulphate (gypsum). Chloride cannot be tested for in the acid solution, as the acid itself would give the reaction.

Flame Coloration

For the flame coloration test scrape off a little of the material, place it on a watch glass and add a few drops of strong hydrochloric acid. Dip the end of a thin piece of clean platinum, iron wire or chrome-nickel wire in the solution and hold it in the outer zone of the flame, about one-third of the way up, and note the colour produced. This may be as follows:

Yellow.—This is the most common, and indicates sodium compounds, but as these are very widely distributed, occurring even in the dust in the air, a yellow coloration, unless very vivid, may be disregarded. Without other tests it is impossible to say what particular sodium compound is present.

Red.—This indicates calcium compounds, such as alabaster (calcite), chalk, gypsum, limestone, marble and whiting.

Blue and Green.—These indicate copper compounds.

Summary of Results of Chemical Tests

Beeswax.—Almost insoluble in alcohol; partly soluble in petroleum spirit (benzine, petrol); largely soluble in turpentine, chloroform and carbon disulphide; melts when heated, and gives a translucent stain on paper; burns with a smoky flame and gives a characteristic smell.

Bitumen (Mineral Pitch).—Insoluble or only slightly soluble in alcohol; soluble or largely soluble in petroleum spirit (benzine, petrol), giving a brown solution which is usually fluorescent; burns with a smoky flame, giving a characteristic smell.

Carbonates.

Calcium Carbonate.—This occurs as alabaster (calcite), chalk, limestone, marble, whiting. It is soluble with vigorous effervescence in hydrochloric acid, and the solution imparts a brick-red colour to the flame.

Sodium Carbonate.—Soluble in water; soluble in hydrochloric acid with strong effervescence; imparts a very vivid yellow colour to the flame; the water solution is alkaline. Sodium carbonate occurs in natron.

Glue.—Softened and finally dissolved by water, the solution frothing readily on agitation; insoluble in alcohol; gives a disagreeable nitrogenous smell on burning.

Gum.—Soluble in water; insoluble in alcohol; does not melt but chars on heating; no nitrogenous smell on burning.

Lapis lazuli.—This is a double silicate of aluminium and sodium associated with sodium sulphide, and contains patches of calcite (calcium carbonate) and often spangles of iron pyrites. It is soluble in strong hydrochloric acid, sulphuretted hydrogen being evolved, and the white patches give effervescence.

Malachite.—This is basic copper carbonate. It is soluble in hydrochloric acid with effervescence, giving a green solution of copper chloride that imparts a blue coloration to the flame. Copper compounds, other than chloride, colour the flame green. Bright steel, such as the blade of a knife, introduced into the hydrochloric acid solution becomes covered with a thin coating of metallic copper.

Natron.—This is a compound of sodium carbonate and sodium bicarbonate, that occurs naturally in Egypt and was used by the ancient Egyptians in embalming; it always contains an admixture of common salt and sodium sulphate, and therefore

will give the reactions for these substances. It imparts a very vivid yellow colour to the flame: it is soluble in water, the solution being alkaline, and it effervesces on the addition of acid.

Resin.—Soluble in strong alcohol; insoluble in water; insoluble or only slightly soluble in petroleum spirit; melts with heat; burns with a smoky flame, giving a characteristic smell like burning varnish.

Salt (*Sodium Chloride*).—Soluble in water, the solution giving a white precipitate with silver nitrate, which is insoluble in nitric acid; neutral to litmus; gives a very vivid yellow flame coloration.

Sulphates.

Calcium Sulphate (*Gypsum*).—Soluble in hydrochloric acid without effervescence, though not very readily soluble unless heated; the solution imparts a brick-red colour to the flame.[1]

Sodium Sulphate.—Soluble in water, the solution giving a white precipitate with barium chloride, which is insoluble in hydrochloric acid; neutral to litmus, and gives a very vivid yellow colour to the flame.

[1] See also p. 229.

BIBLIOGRAPHY

CHAMPION, B. C. "Identification et conservation des objects préhistoriques." *Mouseion*, Vol. 16 (1931).

CHURCH, Sir A. H. *The Chemistry of Paints and Painting*, 1915.

Department of Scientific and Industrial Research. *Dry Rot in Wood*, 1928.

Department of Scientific and Industrial Research. *Report of the Stone Preservation Committee*, 1927.

DE WILD, M. *The Scientific Examination of Pictures*, 1929.

DE WILD, M. "Méthodes de restauration et de conservation des peintures des écoles hollandaise et flamande." *Mouseion*, Vol. 15 (1931).

FIELD, S., and BONNEY, S. R. *The Chemical Colouring of Metals*, 1925.

FINK, G. C., and ELDRIDGE, C. H. *The Restoration of Ancient Bronzes and other Alloys*, 1925.

GAHAN, C. G. *Furniture Beetles.* British Museum (Natural History), 1925.

GIRDWOOD, J. *Worms in Furniture and Structural Timber*, 1927.

HARMER, Sir SYDNEY, F. "Experiments on the Fading of Museum Specimens." *The Museums Journal*, Vol. 21 (1922).

HEATON, NOEL. "The Preservation of Stone." *Journal, Royal Society of Arts*, Vol. LXX (1921).

HIORNS, A. H. *Metal Colouring and Bronzing*, 1920.

HOLMES, Sir CHARLES. "Some Elements of Picture Cleaning." *The Burlington Magazine*, Vol. XL (1922).

LAURIE, A. P. *The Painter's Methods and Materials*, 1926.

LAURIE, A. P. "The Preservation and Cleaning of Pictures." *Connoisseur*, Vol. LXXIII (1925).

LEECHMAN, D. *Technical Methods in the Preservation of Anthropological Museum Specimens*, 1931. (From Annual Report, 1929, National Museum of Canada.)

LUCAS, A. *Disintegration and Preservation of Building Stones in Egypt*, 1915.

LUCAS, A. "Damage caused by Salt at Karnak." *Annales du Service des Antiquités de l'Égypte*, Vol. XXV (1925).

NICHOLS, H. W. *Restoration of Ancient Bronzes and Cure of Malignant Patina*, 1930.

PAPARI, T. V. "Méthodes de conservation des peintures anciennes." *Mouseion*, Vol. 16 (1931).

PETRIE, Sir FLINDERS. *Methods and Aims in Archæology*, 1904.

RATHGEN, F. *Die Konservierung von Altertumsfunden*, 1924.

RATHGEN, F. *The Preservation of Antiquities*. English translation by G. A. and H. A. Auden, 1905.

RHOUSONPOULOS, O. A. "On the Cleaning and Preservation of Antiquities." *The Museums Journal*, Vol. II (1911-12).

RICCI, CORRADO. Les agents atmosphériques et la conservation des œuvres d'art." *Mouseion*, Vol. 15 (1931).

ROSENBERG, G. A. *Antiquités en fer et en bronze, leur transformation . . . et leur conservation*, 1927.

RUHEMANN, H. "La Technique de la conservation des tableaux." *Mouseion*, Vol. 15 (1931).

RUSSELL W. J., and ABNEY, W. DE W. "Action of Light on Water Colours." *Blue Book*, 1888.

SCHAFFER, R. J. *The Weathering of Natural Building Stones*, 1932. Department of Scientific and Industrial Research.

SCOTT, ALEXANDER. *The Cleaning and Restoration of Museum Exhibits*. First Report, 1921 ; Second Report, 1923 ; Third Report, 1926.

TUDOR-HART, P. "Nettoyage, rentoilage et vernissage des peintures." *Mouseion*, Vol. 15 (1931).

INDEX